10/3/19 K.

STAGE I ASSESSMENT PLAN

KALAMAZOO RIVER ENVIRONMENT SITE

Michigan Department of Environmental Quality
Michigan Department of Attorney General
U.S. Fish and Wildlife Service
National Oceanic and Atmospheric Administration

Prepared by:
Stratus Consulting Inc.
PO Box 4059
Boulder, CO 80306-4059

Under subcontract to:
DLZ Corporation

November 2000

Contents

Figures

Tables

1. Introduction

The Director of the Michigan Department of Environmental Quality (MDEQ), the Attorney General of the State of Michigan, and the Secretary of the Interior as represented by the Regional Director of the U.S. Fish and Wildlife Service (U.S. FWS), in coordination with the Secretary of Commerce as represented by the National Oceanic and Atmospheric Administration (NOAA) (collectively referred to as the Trustees), are in the process of assessing damages to natural resources in the Kalamazoo River Environment (KRE) that have resulted from releases of hazardous substances into the KRE. The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) [§ 107 (f), 42 U.S.C. § 9607, as amended] and the Clean Water Act (Federal Water Pollution Control Act, or CWA) [33 U.S.C. § 1321] provide authority to the Trustees to seek such damages. Additionally, the State Trustees have authority to seek the full value of the injuries to natural resources pursuant to Section 20126a(1)(c) of Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), as well as Section 3115(2) of Part 31, Water Resources Protection, of NREPA.

This document presents the Stage I Assessment Plan for the natural resource damage assessment (NRDA) being conducted by the Trustees. The Stage I Assessment Plan, which describes the approach and methods that the Trustees will use in conducting the Stage I assessment, is the second step in the NRDA process and follows the KRE Preassessment Screen prepared by the Trustees in May 2000. The Stage I Assessment Plan was prepared in accordance with the U.S. Department of the Interior (DOI) NRDA regulations as set forth at 43 CFR Part 11.[1] These regulations are not mandatory. However, assessments performed in compliance with these regulations have the force and effect of a rebuttable presumption in any administrative or judicial proceeding under CERCLA [42 U.S.C. § 9607(f)(2)(C)]. The DOI guidelines also provide a useful context within which the various aspects of the assessment can be evaluated, and therefore have been followed in this document.

---

1. 43 CFR Part 11 regulations were authored by the U.S. Department of the Interior (DOI), and are referred to as the DOI regulations in this document.

1.1 The Natural Resource Damage Assessment Process

Certain state and federal agencies that have been designated as Trustees are empowered to obtain compensation from potentially responsible parties (PRPs) for damages for injury to, destruction of, or loss of natural resources caused by hazardous substance releases. Trustees must use recovered funds to restore, replace, rehabilitate, or acquire the equivalent of the injured natural resources. In lieu of receiving funds for damages to natural resources, the Trustees may allow the PRPs to directly implement restoration activities.

Important NRDA terms include:

Injury A measurable adverse change, either long or short term, in the chemical or physical quality or the viability of a natural resource resulting from the release of a hazardous substance [43 CFR § 11.14(v)].

Service The physical and biological functions performed by the resource, including human uses of those functions [43 CFR § 11.14(nn)]. Services may include such features as wildlife habitat, recreation, erosion control, and subsistence.

Damages The amount of money sought by the Trustees as compensation for injury, destruction, and loss of natural resources [43 CFR § 11.14(i)]. All recovered damages must be put toward environmental restoration by the Trustees. The Trustees may also accept restoration activities in lieu of damages.

The DOI regulations for conducting an NRDA involve four major components (Figure 1.1). The first is the development of a **Preassessment Screen,** which determines whether a discharge or release of hazardous substances warrants an NRDA. Preparation of an **Assessment Plan** represents the second phase. The assessment plan is a work plan for the NRDA and ensures that the assessment proceeds in a cost-effective manner. Trustees are required to provide an opportunity for public review of, and comment on, the assessment plan. The third component involves conducting the **Assessment,** which includes performing studies to determine whether injury has occurred, quantifying the injuries and reduction of services, and determining the appropriate restoration actions and compensation for the injuries. The fourth component consists of the **Post-assessment.** A report of assessment containing the results of the assessment work

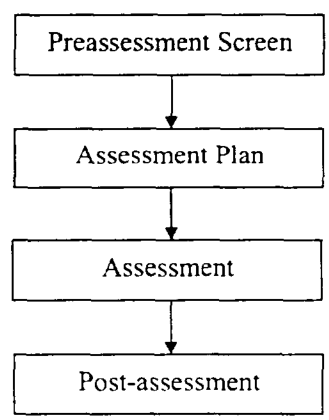

Figure 1.1 Simplified NRDA process.

is prepared and made available to the public. The PRPs are then presented with the amount of money and/or the required restoration activities sought by the Trustees as compensation for injury, destruction, and loss of natural resources, and a restoration plan is developed and implemented.

1.2 The KRE Preassessment Screen

The Trustees released a Preassessment Screen for the KRE NRDA in May 2000. The Preassessment Screen documents the Trustees' determination that there is a reasonable probability of making a successful claim for damages to natural resources and that the Trustees will proceed to the next step of preparing an Assessment Plan.

Specifically, the Preassessment Screen for the KRE concluded the following:

1. *Releases of hazardous substances have occurred* [43 CFR § 11.23(e)(1)]. Numerous investigators, including the Michigan Water Resources Commission, the Michigan Department of Natural Resources (MDNR),[2] Georgia-Pacific, and various contractors have demonstrated that multiple, and at times continuous, releases and re-releases of the hazardous substance polychlorinated biphenyls (PCBs) have occurred and continue to occur as a result of operations at paper company facilities in the KRE. The PRPs that have been identified as having contributed to the releases of PCBs are Allied Paper, Inc. and its parent company, Millennium Holdings, Inc.; the Georgia-Pacific Corporation; Plainwell Inc.; and the Fort James Corporation. The paper company facilities were involved in recycling carbonless copy paper that contained PCBs from the early 1950s through 1971, and the waste management and disposal practices of the facilities resulted in direct releases of PCBs into the KRE.

2. *Natural resources for which the Trustees can assert trusteeship have been, or are likely to be, adversely affected by the release of hazardous substances* [43 CFR § 11.23(e)(2)]. Trustee natural resources that have been affected or potentially affected by releases of PCBs from the PRP facilities include, but are not limited to, surface water resources, including surface water and sediments (bed, bank, and shoreline); groundwater resources; geologic resources, including floodplain soils; aquatic biota, including aquatic

2. Pursuant to State of Michigan Executive Order 1995-18 on October 1, 1995, the division of the MDNR that has responsibility for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site RI/FS and the KRE NRDA was transferred to the Michigan Department of Environmental Quality (MDEQ) (which was created by this Executive Order).

invertebrates and resident and migratory fish; and terrestrial biota, including terrestrial invertebrates, mammals, and birds.

3. *The quantity and concentration of the released substances are sufficient to potentially cause injury to natural resources* [43 CFR § 11.23(e)(3)]. The concentrations of PCBs measured in various KRE media are sufficient to potentially cause injury to KRE natural resources. PCB concentrations exceed injury criteria specified in the DOI NRDA regulations (e.g., surface water quality standards and criteria; Food and Drug Administration tolerance levels), and exceed concentrations at which adverse effects to biological resources are expected.

4. *Data sufficient to pursue an assessment are readily available or likely to be obtained at reasonable cost* [43 CFR § 11.23(e)(4)]. Data relevant to conducting an assessment of natural resource damages in the KRE have been collected as part of ongoing remedial investigation/feasibility study (RI/FS) activities. Such data include information on PCB sources, releases, pathways, and concentrations in the environment. Other potentially relevant data from other sources are also available.

5. *Response actions carried out or planned will not sufficiently remedy the injury to natural resources without further action* [43 CFR § 11.23(e)(5)]. PCBs degrade slowly and are persistent in the environment. Response actions are unlikely to restore the injured natural resources to baseline[3] or compensate the public for losses of natural resource services.

Based on these criteria, the Trustees determined that there is a reasonable probability of making a successful natural resource damages claim, and that they would proceed with the preparation of an Assessment Plan.

1.3 The Stage I Assessment Plan

The Trustees have decided to conduct the NRDA for the KRE site in stages. In Stage I, the Trustees will develop preliminary conclusions regarding the types and magnitudes of injury and damages resulting from hazardous substance releases into the KRE, and will develop preliminary restoration alternatives to address those injuries and damages. The Stage I assessment is intended to be preliminary, relatively rapid, based primarily on existing data, and highly cost-effective. The results of the Stage I assessment will be used by the Trustees to help define any additional focused work that could be conducted in the next stage and, if appropriate, to help evaluate any

3. Baseline is the condition that would have existed in the KRE had the releases of hazardous substances not occurred [43 CFR § 11.14(e)].

potential settlement options. If deemed necessary by the Trustees, a more detailed Stage II assessment may be conducted in which the Trustees conduct focused NRDA studies to address uncertainties in the Stage I assessment.

This Stage I Assessment Plan describes the approach and methods that will be used in the Stage I Assessment. The purpose of the Assessment Plan is to ensure that the assessment is performed in a planned and systematic manner and that the methodologies selected for use in the assessment can be conducted at a reasonable cost [43 CFR § 11.30(b)]. This Stage I Assessment Plan includes:

- descriptions of the geographic areas and natural resources involved [43 CFR § 11.31(a)(2)]
- a statement of the authority for asserting trusteeship, or cotrusteeship, for those natural resources considered within the Stage I Assessment Plan [43 CFR § 11.31(a)(2)]
- information sufficient to demonstrate coordination with remedial investigation and feasibility studies (RI/FS) [43 CFR § 11.31(a)(3)]
- procedures and schedules for sharing data, split samples, and results of analyses with PRPs and other interested parties [43 CFR § 11.31(a)(4)]
- explanation of the decision to proceed with a type B assessment [43 CFR § 11.31(b)]
- the results of confirmation of exposure of natural resources to hazardous substances [43 CFR § 11.31(c)(1)].

A formal Quality Assurance Plan for data collection was not developed specifically for the Stage I Assessment, since the Stage I Assessment relies primarily on data and information that already exist and the collection of new data will be limited [43 CFR § 11.31(c)(2)]. This document does address procedures to assess and ensure the quality of existing data that will be used in the Stage I Assessment Plan and provides information on the sampling protocols and Quality Assurance Plans that will be followed for the limited collection of additional data (Section 5.2).

Because the Stage I assessment is based primarily on existing data, the results of the Stage I assessment may differ from those that would result from a more complete assessment. Nevertheless, conducting the assessment in stages and making use of the data already available for the site is a cost-effective means of conducting the assessment.

1.4 Public Review and Comment

The DOI regulations provide that an Assessment Plan be made available for review and comment by PRPs; other natural resource trustees; other affected federal, state, or tribal agencies; and any other interested members of the public for a period of 30 days. While not required under state law, the Trustees believe that a public comment period is appropriate and will provide an opportunity for involvement by PRPs, other governmental agencies, and the public in this important matter. It may also provide the Trustees with new information and ideas that they may incorporate into their assessment. The Trustees are, therefore, providing a period of 30 calendar days for public comment.

Written comments on the Stage I Assessment Plan may be sent to:

Anne Pulley
Michigan Department of Environmental Quality
Compliance and Enforcement Section
Environmental Response Division
PO Box 30426
Lansing, MI 48909-7926

1.5 Organization of the Stage I Assessment Plan

This Stage I Assessment Plan is organized as follows: Chapter 2 presents an overview of the assessment area and a brief description of PCB releases. Chapter 3 describes the authority of the Trustees to proceed with the assessment and describes the Trustees' decision to proceed with a type B assessment. Chapter 4 provides confirmation that natural resources have been exposed to PCBs in the assessment area and presents a preliminary estimate of the natural recovery period. Chapter 5 describes the approach and methods to be employed by the Trustees in the injury assessment, and Chapter 6 describes the Stage I damage determination process, including both restoration planning and compensable value determination. References cited in the text of the document are provided at the end of the document.

This Stage I Assessment Plan was prepared in response to a work assignment and requests from the Michigan MDEQ to Stratus Consulting, under subcontract to DLZ Corporation.

2. Background Information on the Assessment Area

2.1 Description of the Assessment Area

The Kalamazoo River drainage basin, located in southwestern Michigan, encompasses approximately 5,180 square kilometers (2,000 square miles) (Figure 2.1). The mainstem of the Kalamazoo River is approximately 195 kilometers (120 miles) long and flows from the town of Albion, Michigan, to Lake Michigan near the city of Saugatuck, Michigan. Between Morrow Pond, just upstream of the city of Kalamazoo, and the river mouth, the river alternates between free-flowing sections and a series of dams. The Plainwell, Otsego, and Trowbridge dams have been lowered to their sill levels, exposing former impoundment sediments as floodplain soils (Blasland, Bouck & Lee, 1992). The river is still impounded by the Otsego City, Allegan City, and Lake Allegan (or Caulkins) dams (Blasland, Bouck & Lee, 1992). The lower Kalamazoo River, downstream of Lake Allegan, has been designated a Wild-Scenic River by the Michigan Natural Resources Commission under the Natural Rivers Act (Act 231 of the Public Acts of 1970) (MDNR, 1987b). The Kalamazoo River has several tributaries, including Portage Creek, which is approximately 18.5 miles long (MDNR, 1987b).

The KRE Assessment Area includes natural resources within the Portage Creek and Kalamazoo River riparian corridors and Lake Michigan that are exposed to hazardous substances released from the PRP facilities. Descriptions of the specific resources being addressed in the Stage I assessment are included in Chapter 5.

2.2 PCB Releases to the KRE

PCBs were released into the KRE from various industrial facilities in Kalamazoo and Plainwell. The Trustees have identified Allied Paper, Inc. and its parent company, Millennium Holdings, Inc. (Allied Paper); the Georgia-Pacific Corporation (Georgia-Pacific); Plainwell Inc. (Simpson Plainwell Paper); and the Fort James Corporation (Fort James) as PRPs[1] for the PCB releases. Other PRPs may be named at a later date as information becomes available.

1. The term PRP as used in this document refers to parties potentially liable for natural resource damages under CERCLA and/or under Part 201 of the Michigan Natural Resources Environmental Protection Act, 1994 PA 451, as amended.

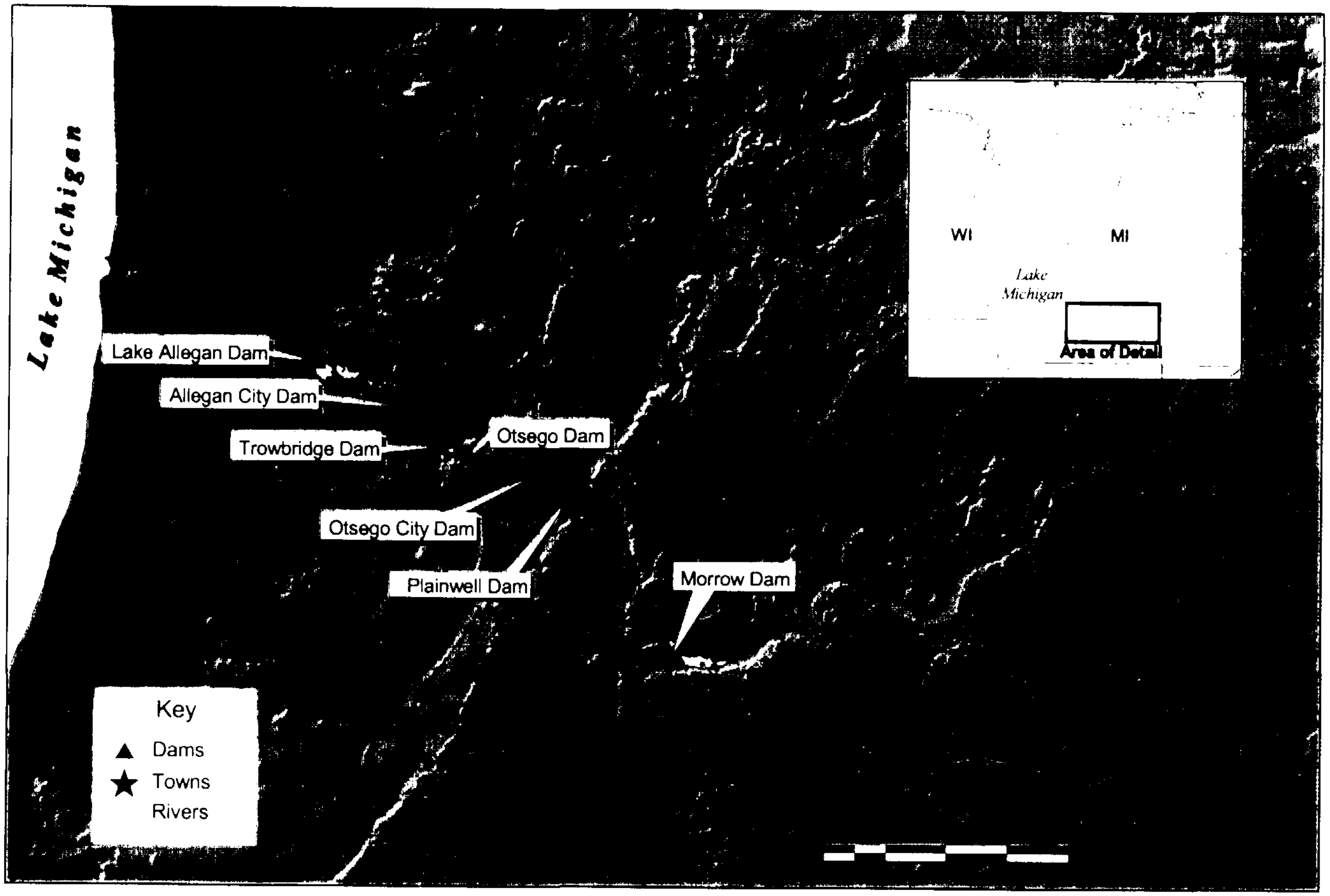

Figure 2.1. Kalamazoo River Environment.

Figure 2.2 shows the general locations of paper mills (or former paper mills) in the Kalamazoo and Plainwell areas. Allied Paper, Inc. facilities include the former Monarch and Bryant mills on Portage Creek in Kalamazoo and the King Mill on Lake Street in Kalamazoo. Georgia-Pacific Corporation facilities include several mills on the bank of the Kalamazoo River in Kalamazoo. Plainwell Inc. facilities include a mill on the bank of the Kalamazoo River in Plainwell. Fort James Corporation facilities include the Paperboard Packaging mill and the KVP Specialty Papers mills in Kalamazoo.

These facilities released PCBs into the KRE through the discharge of wastes produced during the deinking and/or repulping of recycled carbonless copy paper material. PCBs were used as an ink carrier or solvent in carbonless copy paper that was manufactured between 1957 and 1971. The PCBs were used as a solvent for dyes that were encapsulated in small spheres and applied to one side of the paper during the coating process. The walls of the spheres would rupture and release the dye when subjected to pressure. The average PCB content in a sheet of carbonless copy paper was 3.4% by weight (Carr et al., 1977).

The process of deinking and subsequent pulping of the recycled stock resulted in breakage of the spheres that contained the PCBs. These PCBs were then distributed throughout the paper recycling process, including in the waste streams. Some of the PCBs in the carbonless copy paper, however, remained in the recycled pulp and subsequently were incorporated into recycled paper products. For example, PCB concentrations as high as 433 mg/kg were measured in recycled paperboard used for cereal packaging in 1971, the year that PCB use in the manufacturing of carbonless copy paper was discontinued (Carr et al., 1977).

Allied Paper, Georgia-Pacific, and Plainwell Paper Inc. each deinked and repulped recycled carbonless copy paper stock for some period between 1957 and 1971 (the period when PCBs were used in the ink of carbonless copy paper). In addition, the paper recycled by the Kalamazoo-area paper companies most likely continued to contain PCBs for some time after 1971.

Allied Paper deinked carbonless copy paper at two mills: the King Mill until 1965 (the starting date of deinking at this mill is not available), and the Bryant Mill for the entire 15-year period that PCBs were used in the manufacture of carbonless copy paper (1957-1971) (Blasland, Bouck & Lee, 1992). Georgia-Pacific deinked carbonless copy paper at two mills some time during the 1957 to 1971 period when carbonless copy paper contained PCBs (Blasland, Bouck & Lee, 1992). The Simpson Plainwell Paper mill deinked carbonless copy paper from 1957 until 1962 (Blasland, Bouck & Lee, 1992).

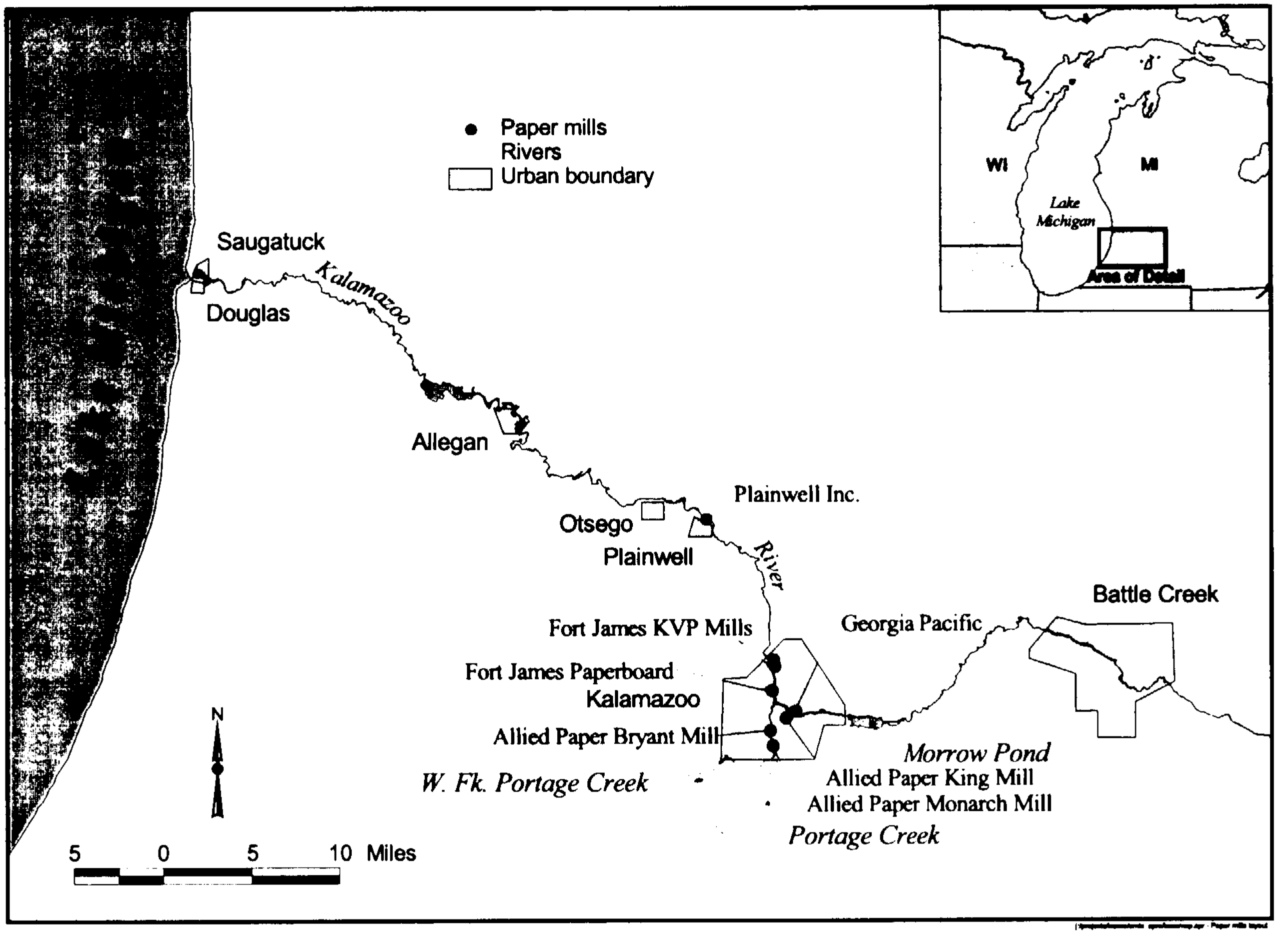

Figure 2.2. Location of PRP paper mill facilities (or former facilities).

The process of deinking and repulping recycled paper produced a substantial quantity of paper waste. Between the mid-1950s and the early 1970s, each of the PRP deinking mills had similar waste treatment systems. Raw paper waste, containing water, clay, and fibrous waste, was pumped to a primary clarifier that separated out much of the settleable solids. The waste from the clarifier included wastewater (effluent) and residual clay and fibrous solids (underflow, or residuals) (Blasland, Bouck & Lee, 1992). However, discharge of untreated waste directly to Portage Creek and the Kalamazoo River also occurred during this (Blasland, Bouck & Lee, 1992).

Typically, the effluent from the clarifier was either recycled through the process systems, discharged to Portage Creek or the Kalamazoo River, or discharged to a municipal wastewater treatment plant (WWTP). The clarifier residuals typically were pumped into dewatering lagoons and allowed to dry by evaporation. The resulting dried residuals, consisting mostly of grey clay and wood fibers, were then removed from the dewatering lagoons and deposited in disposal areas or landfills along Portage Creek and the Kalamazoo River (Blasland, Bouck & Lee, 1992).

Table 2.1 lists PRP facilities where residuals were dewatered or disposed during the period when the waste stream most likely contained PCBs, and includes the maximum PCB concentration that has been measured at each facility. For example, PCB concentrations up to 1,200 mg/kg have been measured in the material at the Bryant historical residual dewatering lagoon along Portage Creek (Blasland, Bouck & Lee, 1992; 1993a). For comparison, PCBs in floodplain soil samples from the Kalamazoo River upstream of PRP facilities ranged from below detection (at detection limits of 0.11 or 0.14 mg/kg) to 0.39 mg/kg (Blasland, Bouck & Lee, 1994a). These data demonstrate that material in the waste stream from the PRP facilities contained elevated concentrations of PCBs.

2.3 RI/FS Activities

A remedial investigation/feasibility study (RI/FS) pursuant to CERCLA (also known as Superfund) is being conducted for the site by MDEQ, U.S. EPA, and the PRPs. The purpose of the RI/FS is to determine the nature and extent of contamination of the site, characterize human health and ecological risks resulting from site contamination, evaluate different alternatives for remediating the site, and selecting the site remedy to address the risks. The RI/FS process and the site remedy are distinct from the site NRDA being conducted by the Trustees. However, the results of the RI/FS remedy selection process influence the NRDA in that the more extensive the PCB cleanup remedy that is conducted, the less NRDA restoration is required. The relationship between RI/FS and NRDA is described in more detail in Section 6.4.

Table 2.1
PRP facilities where recycled paper waste stream material was dewatered or disposed

Facility	Location	Approx. area (hectares)	Approx. area (acres)	Maximum PCB concentration (mg/kg)	Source
Monarch HRDLs[a]	Adjacent to Portage Creek	1	2.47	61	Blasland, Bouck & Lee, 1992; 1993b
Bryant HRDLs[a]	Adjacent to Portage Creek	5	12.36	1,200	Blasland, Bouck & Lee, 1992; 1993b
Bryant Mill Pond	Adjacent to Portage Creek	9	22.24	1,000	Blasland, Bouck & Lee, 1992
A-Site Landfill	Adjacent to the Kalamazoo River in the city of Kalamazoo	9	22.24	148	Blasland, Bouck & Lee, 1992; Swanson Environmental, 1990
Willow Boulevard Landfill	Adjacent to the Kalamazoo River in the city of Kalamazoo	4	9.88	167	Swanson Environmental, 1987
King Highway Landfill	Adjacent to the Kalamazoo River in the city of Kalamazoo	9	22.24	77	Blasland, Bouck & Lee, 1992; 1993a; 1994b
King Mill Lagoons	On Lake Street in the city of Kalamazoo	0.4	0.97	10	Blasland, Bouck & Lee, 1992
12th Street Landfill	Adjacent to the Kalamazoo River in Plainwell	3	7.41	120	Blasland, Bouck & Lee, 1992; Geraghty and Miller, 1994
KVP Type II Landfill	Adjacent to the Kalamazoo River in Parchment	6	14.83	30	STS Consultants, 1989; Williams, 1979
KVP Type III Landfill	Adjacent to the Kalamazoo River in Parchment	10	24.71	(no data available)	STS Consultants, 1989

a. HRDLs = historical residuals dewatering lagoons.

As a result of the PCB releases into the KRE, the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site was added to the National Priorities List (NPL) pursuant to the CERCLA [42 U.S.C. § 9601 *et seq.*, as amended] on August 30, 1990. On December 28, 1990, the State of Michigan entered into an Administrative Order by Consent (hereafter referred to as the Order) with Allied Paper, Inc. and its parent company, Millennium Holdings, Inc. (formerly HM Holdings); the Georgia-Pacific Corporation; and Plainwell Inc. (formerly the Simpson Plainwell Paper Company). Pursuant to the Order, these companies are undertaking a remedial investigation/feasibility study (RI/FS). In addition, the Fort James Corporation (formerly the James River Corporation) is participating in the RI/FS, although it is not a party to the Order. The Allied Paper, Inc./Portage Creek/Kalamazoo River NPL Site includes Portage Creek from Cork Street just above the Bryant Mill Pond in the city of Kalamazoo to its confluence with the Kalamazoo River, and the Kalamazoo River from this confluence downstream to the Allegan City Dam. In total, the initial area under investigation included a 5-km (3-mile) stretch of Portage Creek and a 56-km (35-mile) stretch of the Kalamazoo River.

However, the MDNR expanded the RI to address the Kalamazoo River from Morrow Pond Dam to the mouth of the Kalamazoo River at Lake Michigan [approximately 130 km (80 miles)], as well as Portage Creek from Cork Street to its confluence with the Kalamazoo River [5 km (3 miles)]. In addition, the section of the Kalamazoo River from the Morrow Pond Dam to Lake Michigan is an International Joint Commission Area of Concern.[2]

Work on the RI/FS is ongoing. Records of Decision or proposed plans have been produced for the King Highway Landfill and 12th Street Landfill, and interim response actions have been conducted at the Willow Boulevard/A-Site and the King Mill Lagoons site. In addition, the U.S. EPA and their contractors conducted a time-critical removal cleanup action at the Bryant Mill Pond of Portage Creek beginning in October 1998. The action included removal of PCB-contaminated paper residuals from the creek bed and former impoundment area, and placement of the excavated material on site in the Historic Residual Dewatering Lagoon and the Former Residuals Dewatering Lagoons. Further interim response actions to stabilize the waste that was relocated during the removal action are still in progress.

The Draft RI/FS Report for the Kalamazoo River from Morrow Dam to the Lake Allegan Dam (Calkins Dam) was received by MDEQ on October 30, 2000. An additional RI for the lower reach of the river, from Calkins Dam to Lake Michigan, is expected after additional investigation work in the area, including sampling of sediment and floodplain soil, has been completed.

2. Pursuant to the Great Lakes Water Quality Agreement of 1978 (as amended) between the United States and Canada, the International Joint Commission has identified 43 Areas of Concern throughout the Great Lakes where beneficial uses and/or the ability to support aquatic life is impaired by pollutants (International Joint Commission, 1989).

3. Authority of Trustees and Decision to Proceed with a Type B Assessment

3.1 Authority

Natural resources subject to state and federal trusteeship, and which have been or are likely to have been adversely affected by the releases of hazardous substances, include surface water, sediments, groundwater, soils, and biological resources, including aquatic biota and wildlife.

Under Section 107 (f) of CERCLA, the Trustees, individually and together, are authorized to recover damages for injury to, destruction of, and loss of natural resources resulting from a release of hazardous substances from a facility. The Trustees will coordinate and cooperate in carrying out their trustee responsibilities as suggested under the National Oil and Hazardous Substances Pollution Contingency Plan (NCP): where there are multiple trustees, because of coexisting or contiguous natural resources or concurrent jurisdictions, they should coordinate and cooperate in carrying out their trustee responsibilities [40 CFR § 300.615].

Under the DOI regulations, assessment plans must include a statement of the authority for asserting trusteeship or cotrusteeship for those natural resources within the Assessment Plan [43 CFR § 11.31(a)(2)]. A general description of the natural resource authority asserted by the Trustees is given below. These descriptions are not meant to be an exhaustive and all inclusive listing of their authority over Trustee natural resources. In addition, each Trustee may have co-trustee authority over natural resources listed within the trusteeship of another Trustee.

3.1.1 Michigan Departments of Environmental Quality and Attorney General Natural Resource Trusteeship Authority

The MDEQ is responsible for administering environmental regulatory programs for the State of Michigan. The Michigan Department of Attorney General is responsible for enforcing environmental laws within the State of Michigan. Pursuant to Section 20126a(1)(c) of Part 201, Environmental Remediation, of the Natural Resources and Environmental Protection Act, 1994 PA 451, as amended (NREPA), as well as Section 3115(2) of Part 31, Water Resources Protection, of NREPA, persons who are liable are jointly and severally liable for the full value of injuries to natural resources. The Director of the MDEQ and the Attorney General of the State of Michigan have also been designated by Michigan Governor John Engler as Trustee and Co-Trustee, respectively, for state natural resources pursuant to Section 107(f)(2)(B) of CERCLA

[42 U.S.C. §§ 9601 et seq.] and Section 311 of the Federal Water Pollution Control Act of 1972, as amended (Clean Water Act) [33 U.S.C. §§ 1251 et seq.].

3.1.2 U.S. Department of the Interior and U.S. Department of Commerce Natural Resource Trusteeship Authority

CERCLA and the Clean Water Act authorize the President to recover, on behalf of the public, damages for injuries to natural resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by the United States [42 U.S.C. §§ 9607(f)(1), 9601(16); 33 U.S.C. § 1321(f)(5)]. The President has designated federal natural resource trustees in the NCP [40 CFR § 300.600]. The NCP states that federal natural resource trusteeship extends to resources belonging to, managed by, held in trust by, appertaining to, or otherwise controlled by (referred to as "managed or controlled") by the United States, including supporting ecosystems resources [40 CFR § 300.600].

The Secretary of the Interior acts as Trustee for natural resources managed or controlled by the U.S. DOI, including their supporting ecosystems [40 CFR § 300.600(b), (b)(2), and (b)(3)]. The statutory bases for U.S. DOI's trusteeship include, but are not limited to, the Migratory Bird Treaty Act (16 U.S.C. § 703 *et seq.*), the Bald Eagle Protection Act (16 U.S.C. § 668 *et seq.*), the Fish and Wildlife Coordination Act (16 U.S.C. § 661 *et seq.*), and the Clean Water Act (33 U.S.C. § 1251 *et seq.*).

The Secretary of Commerce acts as Trustee for natural resources managed or controlled by the U.S. Department of Commerce (DOC), including their supporting ecosystems. [40 CFR § 300.600(b), (b)(1)]. The Secretary of DOC has delegated his authority to act as trustee to the Administrator of the National Oceanic and Atmospheric Administration (NOAA) [DOO 15-10 § 3.01 (mm)]. Pursuant to this delegation, NOAA has trusteeship for the natural resources in the KRE and Lake Michigan. Pursuant to the Great Lakes Critical Programs Act of 1990 [33 U.S.C. § 1268] (Great Lakes Act), and the Great Lakes Water Quality Agreement of 1978, as amended by the Water Quality Agreement of 1987 (Great Lakes Water Quality Agreement), the United States, in part through the Commerce Department, manages and/or controls the water and sediments of the Great Lakes System. The water and sediments of the Kalamazoo River and Lake Michigan fall within the Great Lakes System.

3.2 Decision to Perform a Type B Assessment

Trustees can use Type A or a Type B NRDA procedures [43 CFR § 11.33]. Type A procedures are simplified procedures that require minimal field observation [43 CFR § 11.33(a)]. A Type B assessment provides alternative methodologies for conducting NRDAs and consists of three phases: injury determination, injury quantification, and damage determination [43 CFR § 11.60(b)].

Hazardous substances have been released or re-released in the assessment area for over 30 years. Hazardous substances have been transmitted through the food chain, affecting many different trophic levels. Consequently, the releases cannot be considered of a short duration, minor, or resulting from a single event. Further, the spatial and temporal extent and the heterogeneity of exposure conditions and potentially affected resources are not suitable for application of the simplifying assumptions and averaged data and conditions contained in Type A procedures. Therefore, simplified Type A assessment methodologies would be inappropriate for this NRDA.

The Trustees have determined (1) that the Type A assessment is not appropriate for the long-term, spatially, and temporally complex nature of releases and exposures to hazardous substances characteristic of the assessment area; (2) that substantial site-specific data already exist to support the assessment; and (3) that additional site-specific data can be collected at reasonable cost (if required as part of a Stage II assessment). As a result, the Trustees have concluded that the use of Type B procedures is justified.

4. Confirmation of Exposure and Recovery Period

The DOI NRDA regulations state that the assessment plan should confirm that:

> at least one of the natural resources identified as potentially injured in the preassessment screen has in fact been exposed to the . . . hazardous substance [43 CFR § 11.34(a)(1)].

A natural resource has been exposed to a hazardous substance if "all or part of [it] is, or has been, in physical contact with . . . a hazardous substance, or with media containing the . . . hazardous substance" [43 CFR § 11.14(q)]. The DOI regulations also state that "whenever possible, exposure shall be confirmed using existing data" from previous studies of the assessment area [43 CFR § 11.34(b)(1)]. In addition to confirming exposure according to the definition of exposure in the DOI regulations, the Stage I Assessment Plan also provides a comparison of PCB concentrations in natural resources downstream of PRP facilities that are known to have released PCBs to concentrations upstream of these facilities. This comparison is provided for illustrative purposes.

The following sections provide confirmation of exposure, based on a review of the available data, for a number of the potentially injured resources within the KRE Assessment Area, including:

- surface water resources, including surface water and sediments
- groundwater resources
- geologic resources
- biological resources, including benthic macroinvertebrates, fish, and wildlife.

The following discussion provides examples of information sufficient to confirm exposure of surface water/sediment, groundwater, geologic, and biological resources to PCBs in the KRE. It is not a complete review of existing information regarding KRE resource exposure to PCBs.

A preliminary determination of the recovery period for KRE natural resources is also presented in this chapter.

4.1 Surface Water/Sediment Resources

Surface water resources are defined in the DOI regulations as including both surface water and sediments suspended in water or lying on the bank, bed, or shoreline [43 CFR § 11.14(pp)]. Available data on PCB concentrations in surface water and sediment document that these resources are exposed to PCBs in the KRE. PCBs have been measured in Portage Creek and the Kalamazoo River downstream of PRP facilities at concentrations much higher than those measured upstream of PRP facilities.

For example, PCB concentrations measured in Portage Creek surface water in 1993 (before the emergency removal action) by Blasland, Bouck & Lee (2000) were much higher downstream of Allied Paper facilities than those measured upstream (Figure 4.1). Upstream of the facilities, PCBs were detected in only 1 of the 24 surface water samples analyzed at a detection limit of 0.05 μg/L. Downstream of the facilities (at Alcott Street), PCBs were detected in 21 of the 24 samples analyzed and measured up to 0.23 μg/L.

Surface water samples collected between 1985 and 1987 by MDNR in Portage Creek showed a similar pattern. PCBs were detected above the study's 0.01 μg/L detection limit in all 27 downstream samples; concentrations were measured as high as 0.33 μg/L (MDNR, 1987b; Figure 4.2). In contrast, upstream of Allied Paper facilities, only 1 of the 25 samples collected contained PCBs at a detectable concentration (0.02 μg/L).

PCB concentrations measured between 1985 and 1987 in Kalamazoo River surface water show a similar pattern between areas upstream and downstream of PRP facilities (MDNR, 1987b; Blasland, Bouck & Lee, 1992). In general, concentrations of PCBs in Kalamazoo River surface water increase with distance downstream of PRP facilities (Figure 4.3). The minimum values were not detected at a detection limit of 0.01 μg/L and are represented in Figure 4.3 as one-half the detection limit.

PCB concentrations are also elevated in bed sediments of Portage Creek and the Kalamazoo River. Numerous studies measured elevated PCB concentrations in Portage Creek sediment downstream of the Allied Paper facilities (Michigan Water Resources Commission 1973; MDNR 1983, 1984, 1987b; Limno-Tech, 1987; GZA/Donahue, 1990; Blasland, Bouck & Lee, 1992, 1994c). PCB concentrations in sediment samples collected at and downstream of the former Bryant Mill Pond before the emergency removal are one to two orders of magnitude greater than concentrations at upstream locations (Figure 4.4).

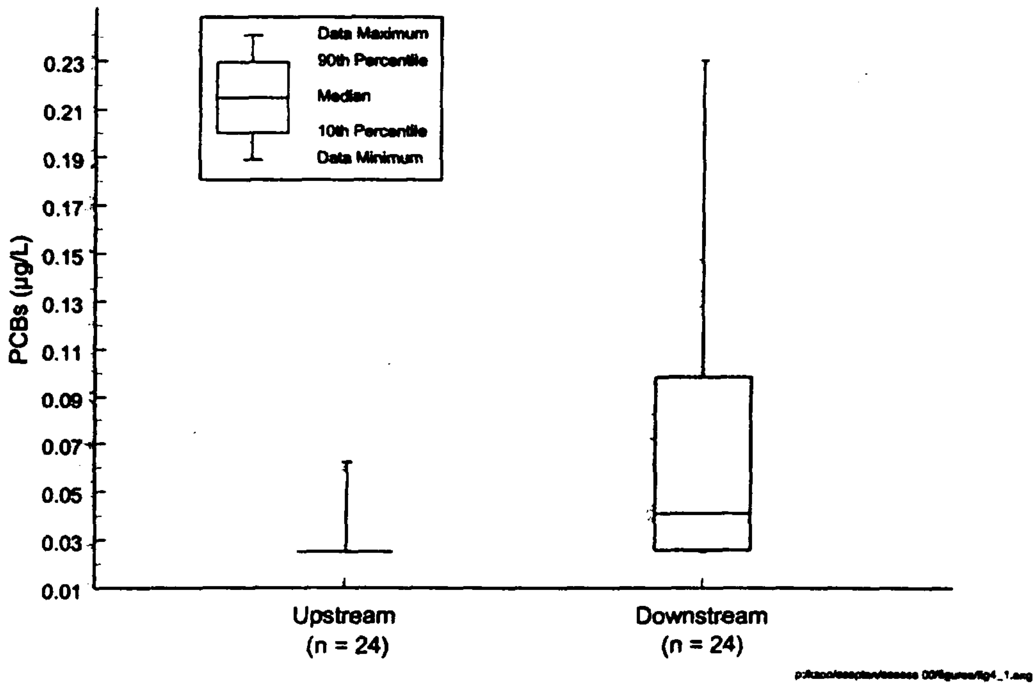

Figure 4.1. Surface water PCB concentrations in Portage Creek upstream (at Cork Street) and downstream (at Alcott Street) of Allied Paper facilities, in 1993.

Samples reported as not detected are plotted at one-half the detection limit of 0.05 µg/L; reported values less than 0.05 µg/L were qualified as "estimated" by the analytical laboratory.

Source: Blasland, Bouck & Lee, 2000.

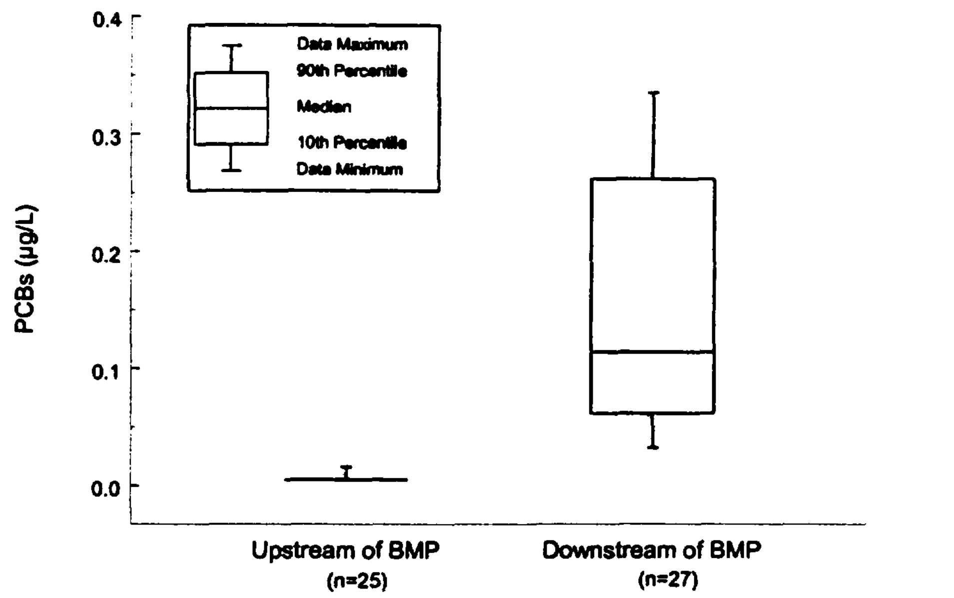

Figure 4.2. Surface water PCB concentrations in Portage Creek upstream (at Cork Street) and downstream (at Alcott Street) of Allied Paper facilities, 1985-1987.

BMP = former Bryant Mill Pond.

Samples reported as not detected are plotted at one-half the detection limit of 0.05 µg/L; reported values less than 0.05 µg/L were qualified as "estimated" by the analytical laboratory.

Source: MDNR, 1987a.

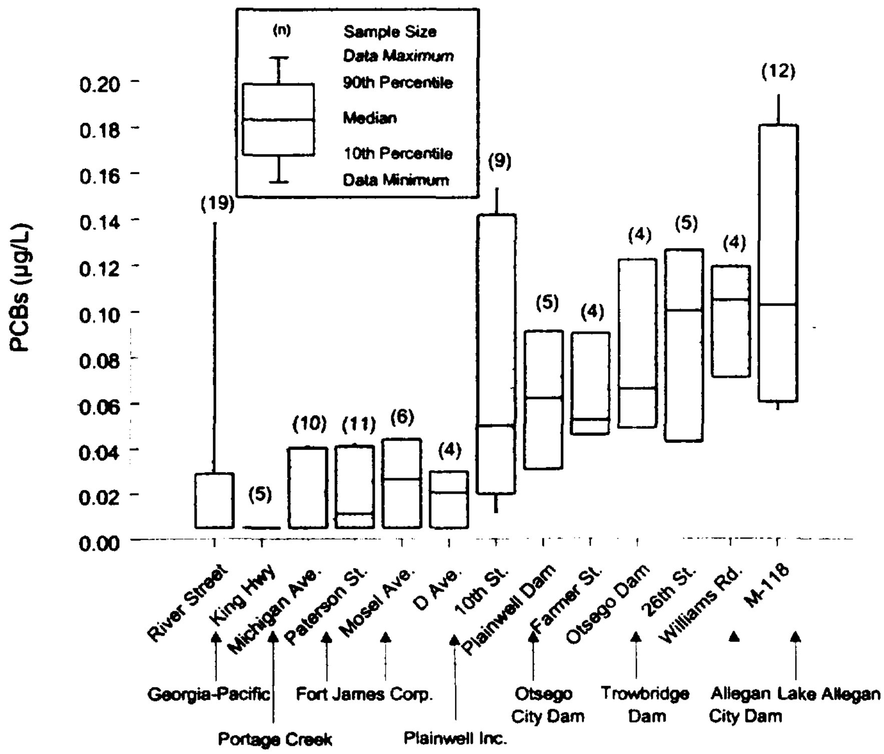

Figure 4.3. PCB concentrations in Kalamazoo River surface water, 1985-1987.

Downstream is to the right.

Source: MDNR, 1987a.

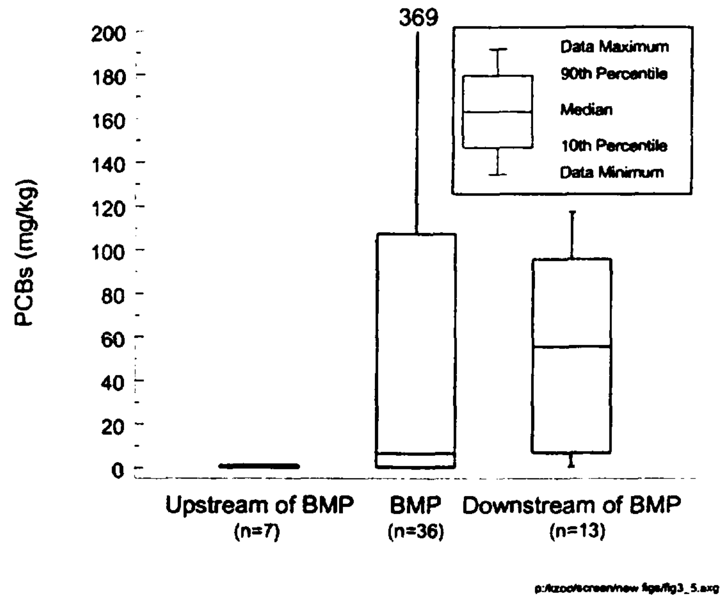

Figure 4.4. PCB concentrations in Portage Creek surficial sediments.

Data for all sampling years and investigations are pooled. BMP = former Bryant Mill Pond. The y-axis is cut off at 200 mg/kg, and the "369" represents the maximum concentration in BMP sediments. See text for data sources.

Studies conducted between 1976 and 1993 measured elevated PCB concentrations in Kalamazoo River sediments (Bhaskar et al., 1983; MDNR, 1983, 1986, 1987a, 1990, 1991; Horvath, 1984; GZA/Donahue, 1988, 1990; Environmental Resources Management, 1989; FTC&H 1991; Blasland, Bouck & Lee, 1992, 1994c). PCB concentrations in sediment samples collected at and downstream of PRP facilities are one to two orders of magnitude greater than concentrations upstream (Figure 4.5).

In summary, elevated PCB concentrations have been measured in surface waters and sediment of the KRE Assessment Area. PCB concentrations measured downstream of PRP facilities that have released PCBs are higher than concentrations measured upstream of the facilities. These data confirm that the KRE surface water resource has been exposed to PCBs.

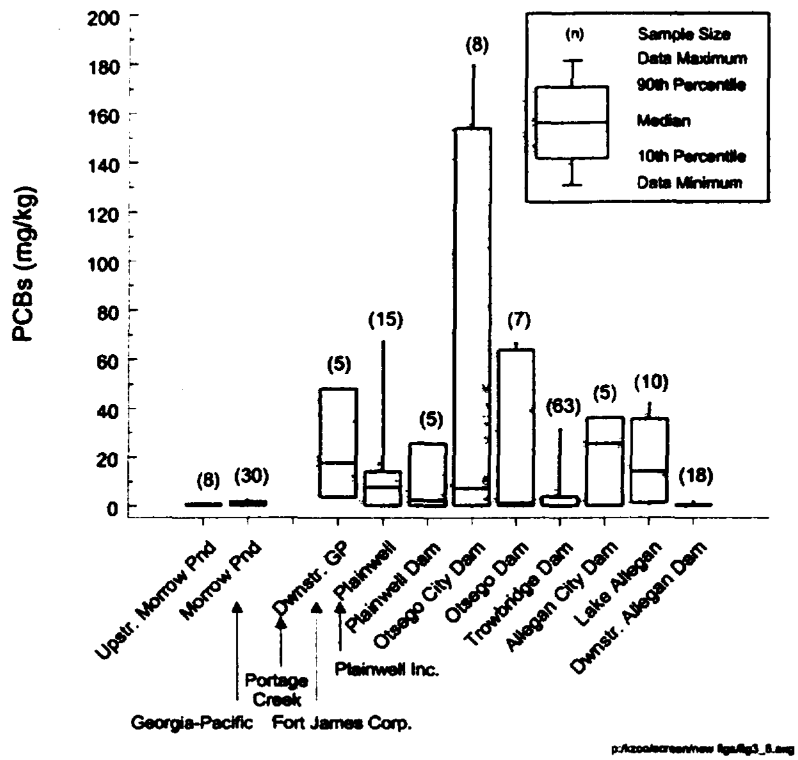

Figure 4.5. PCB concentrations in Kalamazoo River sediments.

Data for all sampling years and investigations are pooled. Morrow Pond is upstream of paper company facilities. GP = Georgia-Pacific facilities. See text for data sources.

4.2 Groundwater Resources

Groundwater is defined in the DOI regulations as "water in a saturated zone or stratum beneath the surface of land or water and the rocks and sediment through which ground water moves" [43 CFR § 11.14(t)]. PCB concentrations in groundwater underlying PRP facilities near Portage Creek were all above detection and ranged from 0.10 to 2.1 μg/L (Table 4.1). Upgradient of the Allied Paper facilities, no PCBs were measured above the detection limit of 0.01 μg/L (MDNR, 1987a). These data show that groundwater in the KRE Assessment Area has been exposed to PCBs.

Table 4.1
Example PCB concentrations in groundwater underlying Allied Paper Portage Creek facilities

Location	PCB concentration (µg/L)	Source
Background		
Upgradient of Allied Paper	<0.01	MDNR, 1987b
Allied Paper Facilities		
Outside Type III landfill, adjacent to Portage Creek	0.52 0.56	MDNR, 1987b
Northeast of Bryant HRDL, ~100 feet from Portage Creek	0.35 0.10	Blasland, Bouck & Lee, 1992
East of Bryant HRDL, ~100 feet from Portage Creek	0.13	
East of Bryant HRDL, ~20 feet from Portage Creek	0.37	
North of Bryant Clarifier, ~150 feet from Portage Creek	2.1 1.7 1.4 0.76 3.3	

4.3 Geologic Resources

Geologic resources are defined in the DOI regulations as "those elements of the Earth's crust such as soils, sediments, rocks, and minerals . . . that are not included in the definitions of ground and surface water resources" [43 CFR § 11.14(s)]. The geologic resources of the KRE include the extensive floodplain soils along Portage Creek and the Kalamazoo River. Some of these soils are located immediately upstream of several of the dams on the Kalamazoo River and consist largely of former sediments that were deposited behind the dams, then exposed when the dams were decommissioned and partially removed (Blasland, Bouck & Lee, 1992). These areas include the former Bryant Mill Pond impoundment on Portage Creek, and the Plainwell, Otsego, and Trowbridge former impoundments on the Kalamazoo River (Blasland, Bouck & Lee, 1992). These floodplain soils exposed by partial dam removal comprise approximately 200 hectares (530 acres) in the KRE (Blasland, Bouck & Lee, 1992).

PCB concentrations up to 55.9 mg/kg, 28 mg/kg, and 81 mg/kg have been measured in floodplain soils from the former Kalamazoo River impoundments of Plainwell, Otsego, and Trowbridge, respectively (MDNR, 1983; 1987b) (Figure 4.6). PCB concentrations in floodplain soils upstream of PRP facilities ranged from below detection (at a detection limit of 0.11 mg/kg) to 0.39 mg/kg (Blasland, Bouck & Lee, 1994a). Elevated PCB concentrations have also been measured in floodplain soils in the city of Kalamazoo (Environmental Resources Management, 1989). These data provide evidence that the floodplain soils of the KRE are exposed to PCBs at elevated concentrations.

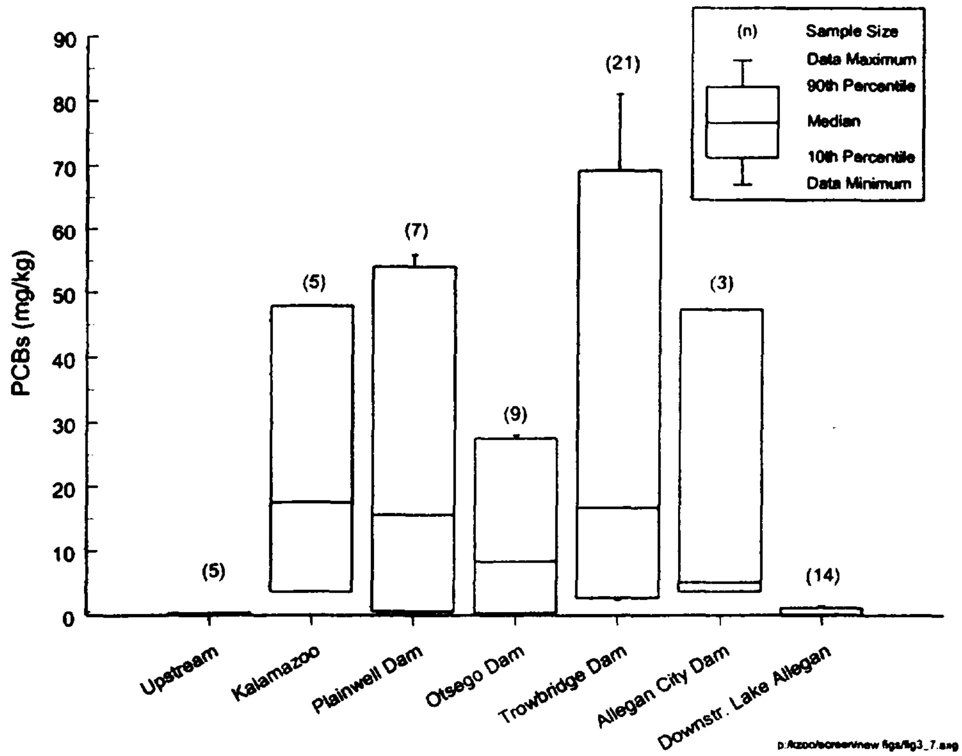

Figure 4.6. PCB concentrations in Kalamazoo River floodplain soils, 1983-1993.

Downstream is to the right.

Sources: MDNR, 1983; 1987b; Environmental Resources Management, 1989; Blasland, Bouck & Lee, 1992, 1994a.

In summary, elevated PCB concentrations have been measured in floodplain soil samples collected from multiple locations in the KRE Assessment Area. These PCB concentrations are higher than concentrations measured in upstream or upgradient locations and confirm that geologic resources have been exposed to PCBs in the KRE Assessment Area.

4.4 Biological Resources

Biological resources are defined in the DOI regulations as "those natural resources referred to in section 101(16) of CERCLA as fish and wildlife and other biota. Fish and wildlife include marine and freshwater aquatic and terrestrial species; game, nongame, and commercial species; and threatened, endangered, and State sensitive species. Other biota encompass shellfish, terrestrial and aquatic plants, and other living organisms" [43 CFR § 11.14(s)]. Data confirming the exposure of KRE biological resources to PCBs are available for fish, birds, invertebrates, and mammals.

4.4.1 Fish

In 1993, as part of RI/FS activities, Blasland, Bouck & Lee (1994a) measured PCB concentrations in skinless carp (*Cyprinus carpio*) fillets and skin-on smallmouth bass (*Micropterus dolomieui*) fillets from 11 locations along the Kalamazoo River. Eleven specimens of each species were collected from each location. PCB concentrations in the skinless carp fillets were an order of magnitude higher in samples from the 80 miles of river downstream of PRP facilities than in samples from upstream locations (Figure 4.7). Similarly, PCB concentrations in skin-on smallmouth bass fillets were also elevated downstream of paper company facilities compared to upstream (Figure 4.8).

Other data on fish fillet PCB concentrations also provide evidence of PCB exposure to fish in the KRE Assessment Area. Data collected for fish in the Kalamazoo River from 1971, and between 1983 and 1987, show elevated PCB concentrations in carp, northern pike (*Esox lucius*), white sucker (*Catostomus commersoni*), largemouth bass (*Micropterus salmoides*), smallmouth bass, black crappie (*Pomoxis nigromaculatus*), bluegill (*Lepomis macrochirus*), channel catfish (*Ictalurus punctatus*), rock bass (*Ambloplites rupestris)*, rainbow trout (*Salmo gairdneri)*, walleye (*Stizostedion vitreum*), and yellow perch (*Perca flavescens*) (Table 4.2).

4.4.2 Birds

PCBs have been measured in birds collected from the KRE Assessment Area. Elevated PCB concentrations have been measured in the edible tissue of various duck species (*Anas* spp.) (MDNR, 1987b; MDPH, 1990; Blasland, Bouck & Lee, 1992). Table 4.3 shows lipid-normalized

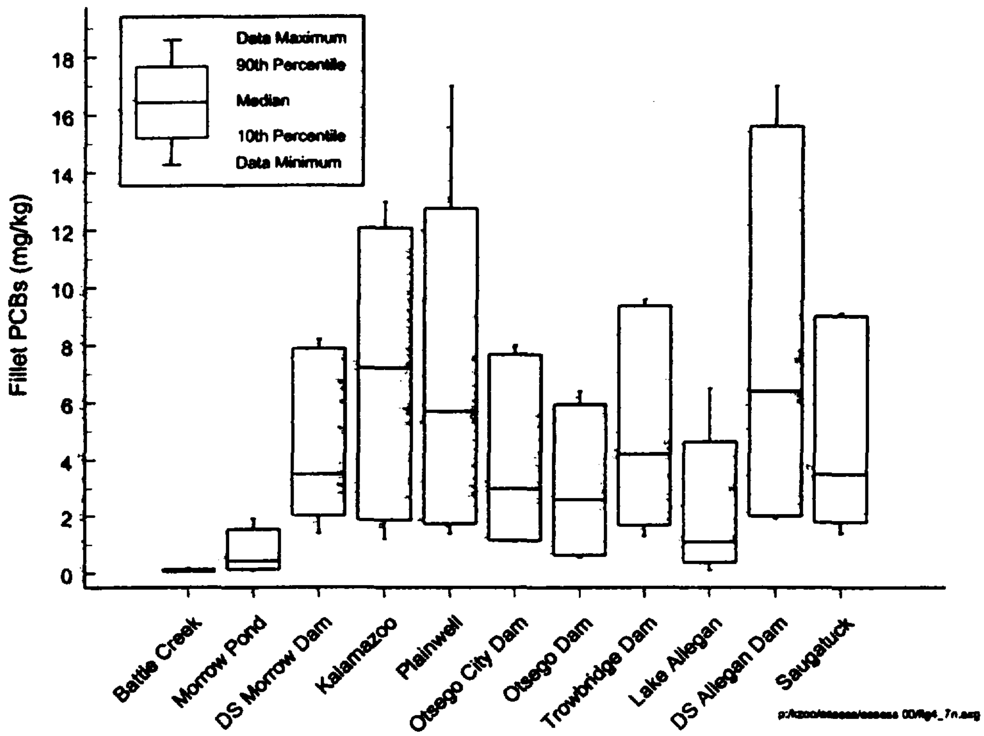

Figure 4.7. PCB concentrations in Kalamazoo River skinless carp fillets, 1993.

Downstream is to the right. Battle Creek and Morrow Pond locations are upstream of PRP facilities. Sample size at all sites is 11 carp.

Source: Blasland, Bouck & Lee, 1994a.

PCB concentrations measured in tissues of 15 mallards (*Anas platyrhynchos*), two wood ducks (*Aix sponsa*), a merganser (*Mergus* spp.), a Canada goose (*Branta canadensis*), and a blue-winged teal (*Anas discors*) collected in the KRE Assessment Area. Concentrations (normalized for lipid content of the tissue) up to 700 mg/kg lipid were measured in these birds.

Elevated concentrations of PCBs have also been measured in bird eggs collected from the KRE Assessment Area. Elevated PCB concentrations have been measured in bald eagle (*Haliaeetus leucocephalis*) and great blue heron (*Ardea herodias*) eggs (Table 4.4) and in great horned owl (*Bubo virginianus*) and red-tailed hawk (*Buteo jamaicensis*) eggs (Table 4.5). For example, a PCB concentration of 102 mg/kg was measured in a bald eagle egg collected in 1994 (Table 4.4) and of 90.8 mg/kg in a great horned owl egg collected in 1993 (Table 4.5).

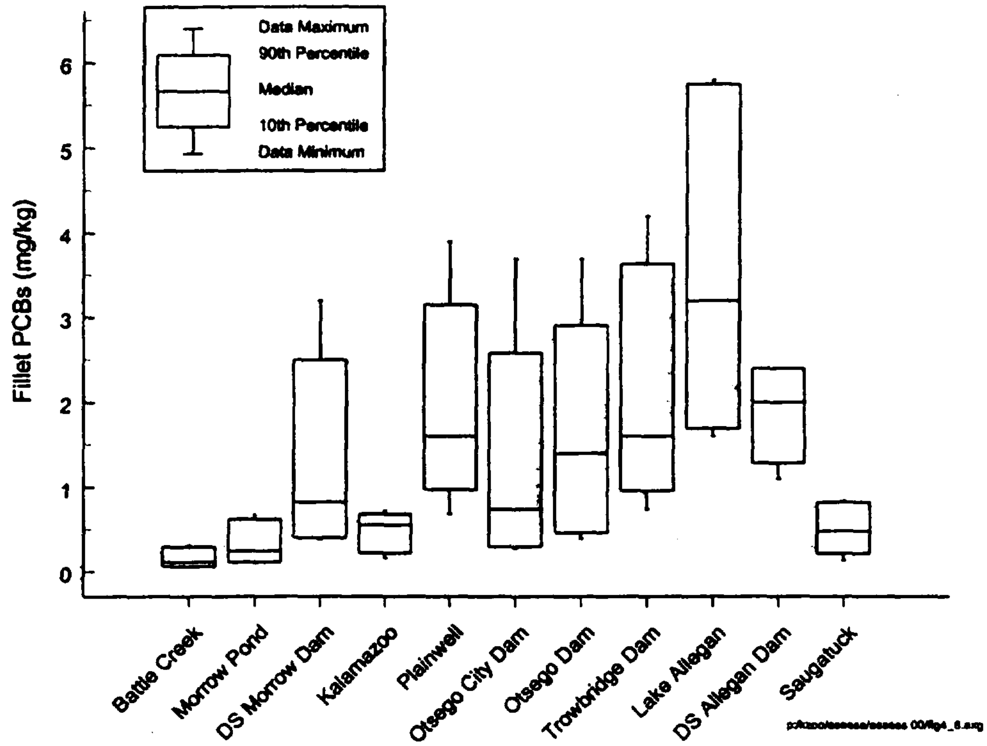

Figure 4.8. PCB concentrations in Kalamazoo River skin-on smallmouth bass fillets, 1993.

Downstream is to the right. Battle Creek and Morrow Pond locations are upstream of PRP facilities. Sample size at all sites is 11 bass.

Source: Blasland, Bouck & Lee, 1994a.

4.4.3 Terrestrial invertebrates

Exposure of KRE terrestrial invertebrates to PCBs has been confirmed by measurement of PCBs in earthworms. PCB concentrations are elevated in earthworms collected from floodplains downstream of PRP paper facilities compared to those collected in Battle Creek, upstream of the facilities (Blasland, Bouck & Lee, 1994a). No PCBs were detected (at detection limits ranging from 0.05 to 0.25 mg/kg) in any of the three composite samples of earthworms collected from floodplain soils upstream of PRP facilities (Table 4.6). Downstream of PRP facilities, PCBs were detected in 100% of the earthworms sampled, at concentrations up to 3.2 mg/kg.

Table 4.2
Summary of historical data on Kalamazoo River fish fillet PCB concentrations downstream of PRP facilities

Sample year	Species	n	Minimum PCB concentration (mg/kg)	Mean PCB concentration (mg/kg)	Maximum PCB concentration (mg/kg)
1971	Carp	12	0.2	29.5	164.6
	Northern pike	7	0.1	6.9	17.6
	White sucker	11	<0.1	17.0	56.9
1983	Carp	26	<0.9	4.0	15.9
1984	Carp	11	1.0	8.5	25.7
1985	Carp	109	<0.1	4.0	14.0
	Largemouth bass	19	0.5	2.0	6.5
	Smallmouth bass	11	0.8	1.7	3.3
1986	Carp	165	<0.1	4.1	27.4
	Largemouth bass	5	<0.1	0.6	1.1
1987	Black crappie	10	0.3	0.7	1.6
	Bluegill	10	0.2	0.4	0.7
	Channel catfish	8	3.5	6.4	12.4
	Carp	47	0.1	2.7	17.1
	Largemouth bass	11	<0.1	1.0	2.0
	Northern pike	14	0.3	1.5	3.4
	Rock bass	10	0.2	0.4	0.5
	Rainbow trout	10	0.2	0.4	0.7
	Smallmouth bass	21	<0.1	1.8	5.1
	Walleye	10	0.3	0.6	1.5
	White sucker	10	0.4	1.1	2.8
	Yellow perch	10	0.1	0.4	1.2

n = number of samples.

Source: MDNR, 1992; Michigan Water Resources Commission, 1972.

4.4.4 Mammals

PCB concentrations have been measured in white-footed mice (*Peromyscus leucopus*) collected from floodplain soils upstream and downstream of PRP facilities (Blasland, Bouck & Lee, 1994a). Upstream of PRP facilities, PCBs were not detected in any of the 10 mice collected, at detection limits ranging from 0.011 to 0.098 mg/kg. At the downstream locations, PCBs were detected in 70% to 100% of the mice collected at concentrations up to 0.45 mg/kg (Table 4.7).

Table 4.3
PCB concentrations (fat basis) in KRE ducks and geese

Location	Species	Measured PCB concentration (mg/kg lipid)	Source
Morrow Pond (upstream of paper companies)	Merganser	700	MDNR, 1987b
Otsego City Dam Impoundment	Mallard	68	Blasland, Bouck & Lee, 1992
	Mallard	65	
	Blue-winged teal	9.6	
Former Trowbridge Impoundment	Mallard	68	Blasland, Bouck & Lee, 1992
	Mallard	73	
Lake Allegan	Wood duck	36.6	Blasland, Bouck & Lee, 1992
	Canada goose	6.4	
Pottawatamie Marsh	Mallard	1.8	MDPH, 1990
	Mallard	7.7	
Saugatuck	Mallard	11.8	MDNR, 1987b
	Mallard	9.3	
	Mallard	7.1	
	Mallard	10.7	
	Mallard	23.0	
	Mallard	11.9	
	Mallard	48.7	
	Wood duck	2.7	
	Mallard	30.3	
	Mallard	36.3	

PCB concentrations have also been measured in mink (*Mustela vison*) collected from the KRE Assessment Area. In 1993, the MDNR collected 10 mink from five locations along the Kalamazoo River and analyzed each of the carcasses and livers for PCBs (CDM, 1993; Roy F. Weston Inc., 1994). At the location upstream of PRP facilities, PCB concentrations ranged from 1.9 to 6.5 mg/kg in carcasses and 1.2 to 6.0 mg/kg in livers. In contrast, PCB concentrations were as high as 16 mg/kg in carcasses and 52 mg/kg in livers downstream of PRP facilities (Table 4.8).

In 1994, the MDNR collected muskrat (*Ondatra zibethaca*) from five locations along the Kalamazoo River: one upstream of Battle Creek and four downstream of paper company facilities (Roy F. Weston Inc., 1994). Six muskrat were trapped at each location. PCBs were not detected in the carcass or liver of any of the muskrat collected from the upstream location,

Table 4.4
PCB concentrations in KRE bald eagle and great blue heron eggs

Species	Collection year	Collection location	PCB concentration (mg/kg wet weight)	Source
Great blue heron	1993	Ottawa Marsh	1.48	Mehne, 1994
			2.3	
			2.31	
			4.74	
			7.67	
			44.38	
Bald eagle	1994	Ottawa Marsh	102	D. Best, U.S. Fish and Wildlife Service, pers. comm., 1997
Bald eagle	1996	Allegan State Game Area	53.34	D. Best, U.S. Fish and Wildlife Service, pers. comm., 2000
			31.68	

Table 4.5
PCB concentrations in KRE great horned owl and red-tailed hawk eggs

Species	Collection year	Collection location	PCB concentration (mg/kg wet weight)
Great horned owl	1993	Allegan State Game Area	90.8
	1994	Allegan State Game Area	15.9
Red-tailed hawk	1993	Allegan State Game Area	2.3
	1994	Allegan State Game Area	4.5
	1994	Allegan State Game Area	27.1
Source: Mehne, 1994.			

at detection limits ranging from 0.12 to 0.59 mg/kg (Table 4.9). PCB concentrations were up to 8.4 mg/kg in muskrat carcasses and up to 3.8 mg/kg in muskrat livers from locations downstream of PRP facilities (Table 4.9).

In summary, elevated PCB concentrations have been measured in KRE biological resources, including fish, birds, terrestrial invertebrates, and mammals. Data demonstrate that PCB concentrations in biological resources are higher downstream of PRP facilities than upstream.

Table 4.6
PCB concentrations in earthworms from Kalamazoo River floodplains

Location	Number of samples	Median (mg/kg wet weight) (range)	% Detect
Battle Creek (upstream of paper companies)	3	nd	0%
Former Plainwell Impoundment	3	0.59 (0.13-0.66)	100%
Downstream of Otsego Dam	3	2.2 (1.3-2.2)	100%
Former Trowbridge Impoundment	3	2.5 (2.1-3.2)	100%
Lake Allegan Dam	3	0.024 (0.23-0.25)	100%

nd = Not detected at detection limits ranging from 0.05 to 0.25 mg/kg wet weight.

Source: Blasland, Bouck & Lee, 1994a.

Table 4.7
PCB concentrations in whole-body white-footed mice collected from Kalamazoo River floodplains

Location	Number of samples	Median[a] (mg/kg wet weight) (range)	% Detect
Battle Creek (upstream of paper companies)	10	nd	0%
Former Plainwell Impoundment	10	0.11 (nd-0.28)	70%
Downstream of Otsego Dam	10	0.28 (0.089-0.38)	100%
Former Trowbridge Impoundment	10	0.115 (nd-0.45)	80%
Lake Allegan Dam	10	0.036 (nd-0.35)	80%

a. Median of detected concentrations.
nd = Not detected at detection limits ranging from 0.011 to 0.098 mg/kg wet weight.

Source: Blasland, Bouck & Lee, 1994a.

Table 4.8
PCB concentrations in KRE mink

Location	Number of samples	Median (mg/kg dry weight) (range)	% Detect
Mink carcass			
Battle Creek (upstream of paper companies)	5	3.0 (1.9-6.5)	100%
Former Plainwell Impoundment	1	7.6	100%
Former Trowbridge Impoundment	2	13.5 (11.0-16.0)	100%
Lake Allegan Dam	2	8.6 (5.2-12.0)	100%
Mink liver			
Battle Creek (upstream of paper companies)	5	3.3 (1.2-6.0)	100%
Former Plainwell Impoundment	1	11.0	100%
Former Trowbridge Impoundment	1	7.5	100%
Lake Allegan Dam	2	30.5 (9.0-52.0)	100%
Source: Roy F. Weston Inc., 1994.			

4.5 Recovery Period

This section provides a preliminary determination of the recovery period for the exposed natural resources of the assessment area [43 CFR § 11.31(a)(2)]. This preliminary determination can serve as a means of evaluating whether the approach proposed for assessing the injuries and damages in Chapters 5 and 6 is likely to be cost-effective [43 CFR § 11.31(a)(2)]. This preliminary determination is based on existing literature and data.

A recovery period is defined as either the longest length of time required to return the services of the injured resource to their baseline condition, or a lesser period of time selected by the Trustees and documented in the Assessment Plan [43 CFR § 11.14(gg)]. Services are defined as the

Table 4.9
PCB concentrations in KRE muskrat

Location	Number of samples	Median (mg/kg dry weight) (range)	% Detect
Muskrat carcass			
Battle Creek (upstream of paper companies)	6	nd	0%
Former Plainwell Impoundment	6	1.0 (0.081-2.0)	100%
Former Otsego Impoundment	6	0.46 (0.14-0.99)	100%
Former Trowbridge Impoundment	6	0.58 (0.28-8.4)	100%
Lake Allegan Dam	6	1.9 (nd-3.1)	83%
Muskrat liver			
Battle Creek (upstream of paper companies)	6	nd	0%
Former Plainwell Impoundment	6	0.93 (0.12-2.6)	100%
Former Otsego Impoundment	6	0.40 (0.12-1.0)	100%
Former Trowbridge Impoundment	5[a]	1.4 (0.23-3.8)	100%
Lake Allegan Dam	6	1.4 (0.33-1.9)	100%

nd = Not detected at detection limits ranging from 0.12 to 0.59 mg/kg.
a. One muskrat liver sample from this location was lost in processing.

Source: Roy F. Weston Inc., 1994.

physical and biological functions performed by the resource, including the human uses of those functions. These services are the result of the physical, chemical, or biological quality of the resource [43 CFR § 11.14(nn)]. The following factors may be considered in estimating recovery times [43 CFR § 11.73(c)(2)]:

- ecological succession patterns in the area
- growth or reproductive patterns, life cycles, and ecological requirements of biological species involved, including their reaction or tolerance to the hazardous substance involved

- bioaccumulation and extent of hazardous substances in the food chain
- chemical, physical, and biological removal rates of the hazardous substance from the media involved.

This preliminary determination of recovery period for the KRE Assessment Area focuses on natural processes related to the loss of PCBs from the environment. KRE natural resources will remain exposed to PCBs as long as environmental media such as soils, sediments, groundwater, and surface water remain contaminated and continue to operate as exposure pathways. This Stage I Assessment Plan considers the recovery period to be the longest length of time required to return the services of the injured resources to baseline [43 CFR § 11.14(gg)].

PCBs are highly persistent compounds and degrade very slowly (Eisler, 1986; Erickson, 1997). In fact, their resistance to most chemical degradation processes is one of the key features that led to their widespread use (Erickson, 1997). However, PCBs can be degraded by microbial communities under both aerobic (i.e., in the presence of oxygen) and anaerobic (i.e., with no oxygen present) conditions. Both aerobic degradation and anaerobic dechlorination have been documented in sediments from PCB-contaminated aquatic systems (e.g., Brown and Wagner, 1990; Flanagan and May, 1993), although these processes are much slower for PCBs than for other compounds (Erickson, 1997). Where it occurs, aerobic microbial degradation acts primarily on selected lower chlorinated PCB congeners,[1] ultimately producing carbon dioxide, water, and chloride ions (Erickson, 1997). Anaerobic microbial degradation involves dechlorination, where chlorine atoms are preferentially removed from the higher chlorinated congeners and lower chlorinated PCB congeners are produced (Brown et al., 1987; Abramowicz et al., 1993). Anaerobic dechlorination does not reduce the amount of PCBs present, but reduces the number of chlorine atoms on the PCB molecules that are subject to dechlorination.

The ability of anaerobic microbial communities to dechlorinate PCB congeners is congener- and site-specific, with different river systems showing different patterns of dechlorination, presumably related at least in part to differences in microbial communities present (Brown et al., 1987; Rhee et al, 1993a; Sokol et al., 1994). The total PCB sediment concentration is also a primary factor regulating PCB dechlorination, with dechlorination rates increasing with increasing sediment PCB concentration (Abramowicz et al., 1993). An apparent threshold concentration may exist below which dechlorination is very slow or does not occur. For example, in PCB contaminated reaches of the Hudson River, a PCB contaminated Superfund site in New York, a threshold sediment concentration of 30 mg/kg was estimated for dechlorination of PCBs (U.S. EPA, 1997). Sokol et al. (1998) also observed a similar threshold concentration for PCB

1. PCBs is a class of compounds that consists of 209 unique compounds that differ in the number and distribution of chlorine atoms on a biphenyl structure. Each of the 209 compounds is called a PCB congener.

dechlorination in sediment collected from PCB-contaminated reaches of the St. Lawrence River; no dechlorination was detected at concentrations below a threshold of between 35 and 45 mg/kg. However, a recent evaluation of dechlorination studies conducted as part of the U.S. EPA's reassessment of the Hudson River PCB Superfund site concluded that a threshold concentration for dechlorination is not supported by the available data (Eastern Research Group, 1999). While dechlorination is predictable at higher PCB concentrations, there is some uncertainty regarding whether dechlorination occurs at lower concentrations (Eastern Research Group, 1999). Rhee et al. (1993b) observed that dechlorination did not occur at elevated PCB concentrations (e.g., as elevated as 1,000 or 1,500 mg/kg), indicating that dechlorination may be inhibited at extremely elevated PCB concentrations as well.

As summarized in Sokol et al. (1998), natural recovery via anaerobic dechlorination appears to be limited for the following reasons:

- Chlorine removal decreases as sediment PCB concentration decreases.
- Chlorine removal is limited by the position and pattern of chlorine substitution on the biphenyl molecule.
- Chlorine removal appears to be limited below a threshold concentration of approximately 30 mg/kg.

For example, in the Hudson River it has been estimated that dechlorination reduced the original PCB concentrations (on a mass basis) present in the river by less than 10% (U.S. EPA, 1997). For the Hudson River, U.S. EPA (1997) concluded that the remaining PCBs would not be further naturally remediated via dechlorination.

Other natural processes related to the loss of PCBs include volatilization and desorption into the water column (from the sediment) and migration downstream. However, both of these processes typically are slow relative to the mass of PCBs in the sediment because of the very low vapor pressure and extreme hydrophobicity of PCB molecules (Erickson, 1997).

Because of the persistence of PCBs in the environment, natural recovery of PCB contamination will proceed very slowly in the KRE. Sediment burial and downstream particulate transport are typically the primary loss mechanism for PCBs in riverine systems (e.g., Velleux and Endicott, 1994). However, PCBs buried in deeper sediment can be re-exposed through anthropogenic activities (e.g., dredging, boating) or through high-flow events. Although the Trustees are unable to quantify an expected natural recovery period for the KRE at this time, the chemical nature of PCBs and what is known regarding loss of PCBs from environmental systems demonstrate that the natural recovery period is expected to be very long, at least on the order of many decades.

5. Stage I Injury Assessment

Chapter 4 provided information that confirmed that natural resources in the KRE Assessment Area, including surface water, sediments, groundwater, soils, and biological resources, have been exposed to PCBs. To evaluate the nature, extent, and degree of injury to exposed natural resources, the Trustees will conduct a Stage I injury assessment. The purpose of the injury assessment is to determine whether natural resources have been injured [43 CFR § 11.61], to identify the environmental pathways through which injured resources have been exposed to hazardous substances [43 CFR § 11.63], and to quantify the degree and extent (spatial and temporal) of injury [43 CFR § 11.71].

As discussed in Chapter 1, the Trustees will conduct the KRE NRDA in stages. The Stage I assessment will be conducted primarily with existing information, supplemented with a limited amount of additional data. If deemed necessary, a more complete State II assessment may be conducted to address uncertainties in the Stage I assessment.

5.1 Injury Assessment Approach

Injury is defined in the DOI regulations as a "... measurable adverse change, either long- or short-term, in the chemical or physical quality or the viability of a natural resource resulting either directly or indirectly from exposure to a ... release of a hazardous substance, or exposure to a product of reactions resulting from the ... release of a hazardous substance. As used in this part, injury encompasses the phrases 'injury,' 'destruction,' or 'loss'" [43 CFR § 11.14(v)].

The injury assessment will involve two basic steps, injury determination and injury quantification.

1. ***Injury determination.*** The Trustees will determine whether an injury to one or more natural resources has occurred as a result of releases of hazardous substances [43 CFR § 11.62].

2. ***Injury quantification.*** The injuries determined by the Trustees will be quantified in terms of changes from "baseline conditions"[1] [43 CFR § 11.71(b)(2)]. Quantification will address both the spatial and temporal extent of injury, as well as evaluation of the degree

1. Baseline conditions are the conditions that would have existed at the assessment area had the release of the hazardous substance not occurred [43 CFR § 11.14(e)].

of injury. Quantification will be conducted primarily to provide information that is relevant to the damage determination and to restoration planning.

As described in the Preassessment Screen for the KRE Assessment Area, natural resources under the trusteeship of the Trustees that have been potentially injured by releases of PCBs from the PRP facilities include, but are not limited to, surface water resources, including surface water and sediments (bed, bank, and shoreline); groundwater resources; geologic resources, including floodplain soils adjacent to Portage Creek and the Kalamazoo River; aquatic biota, including aquatic invertebrates and resident and migratory fish; and terrestrial biota, including terrestrial invertebrates, mammals, and birds (Stratus Consulting, 2000). Consistent with the Preassessment Screen, the Stage I injury assessment will address these natural resources. If the evaluation of existing data indicates that additional natural resources are potentially injured, then these natural resources will also be addressed in the Stage I injury assessment.

Consistent with the DOI regulations, injury determination and quantification will be evaluated on a resource-by-resource basis. However, natural resources and the ecological services they provide are interdependent. For example, surface water, bed, bank, and suspended sediments, floodplain soils, and riparian vegetation together provide habitat – and lateral and longitudinal connectivity between habitats — for aquatic biota, semi-aquatic biota, and upland biota dependent on access to the river or riparian zone. Hence, injuries to individual natural resources may cause ecosystem-level service reductions. Overall, it is the entire KRE ecosystem and associated ecosystem services that may be injured as a result of the releases of hazardous substances from the PRP facilities to natural resources. Hence, while this Stage I assessment will be conducted on a resource-by-resource basis, the evaluation of injury and damage determination will also incorporate ecosystem processes that encompass the loss of ecosystem services within and across these natural resources (see Chapter 6).

5.2 Data Sources

This Section describes the data and information sources that will be used in the Stage I injury assessment. The Stage I injury assessment will rely primarily on data and information already available, supplemented with limited time-critical and opportunistic sampling that will be conducted by the Trustees.

5.2.1 Available Data

The Trustees will gather and analyze available information relevant to assessing injuries resulting from PCB releases into the KRE. Data sources that will be evaluated in the Stage I injury assessment include:

- articles published in the peer-reviewed literature
- state and federal government reports and data
- industry reports and data
- RI/FS reports, including technical memoranda
- long-term monitoring data being collected for the site
- the KRE ecological risk assessment, including information used to support the ecological risk assessment
- ongoing ecological or toxicological studies being conducted by various investigators.

Several ongoing studies or soon-be-initiated studies will produce data potentially relevant to the Stage I injury assessment. For example, Michigan State University has received funding from the PRPs to conduct additional ecological and toxicological studies that may provide valuable information for the injury assessment. Therefore, the Trustees will monitor relevant studies being conducted by these and other researchers, and, if appropriate, will participate in the studies by reviewing study plans, observing field work, and splitting samples for independent analysis. This work will help ensure the usability of the data for the NRDA injury assessment.

Only information that has sufficient supporting documentation will be used in the Stage I assessment. Data sources will be screened to verify that supporting documentation is available and sufficient to allow for an evaluation of the reliability and usability of the information. Data sources should have the following types of supporting documentation available to be considered usable:

- sampling methodology, including information on sample location, environmental media sampled, and measurement units
- chemical analysis, including information on detection limits and methodology
- raw data or data tabulations (e.g., rather than figures only)
- accompanying quality assurance/quality control (QA/QC) data or separate QA/QC reports.

This supporting documentation will be evaluated for each potential data source to determine the acceptability of the data for the Stage I assessment.

Data considered acceptable for the Stage I assessment will be compiled into electronic databases for analysis. The development of these databases (i.e., data entry and validation) and subsequent data analysis (statistical analysis, generation of figures) will be conducted following a strict program of QA/QC. The overall objective of this QA/QC program will be to ensure that the data used in the Stage I assessment are an accurate representation of the data as presented in the original document or data source. Steps that will be taken to ensure data quality will include validation of all data entered into the databases (to eliminate data entry mistakes), review of all calculations performed on the data (including verification of all mathematical equations), and compilation and review of computer logs to track database changes and modifications.

5.2.2 Supplemental Data Collection

The Trustees anticipate collecting limited additional data on the current or recent exposure of selected bird species to PCBs and other contaminants in the KRE. These data will be used in the Stage I injury assessment to help determine the likelihood that PCB concentrations are sufficient to cause injury to birds, as described in Section 5.4.5. The supplemental Trustee data will include the following:

- The results of the chemical analysis of great horned owl and red-winged blackbird eggs that were collected from the KRE by the Trustees in the spring of 2000. This egg collection was a time-critical sample collection to provide data on recent exposure of KRE bird eggs to PCBs and other contaminants.

- The results of KRE bald eagle reproduction monitoring that will be conducted in the spring of 2001 and chemical analysis of bald eagle eggs and serum collected in the past by the U.S. Fish and Wildlife Service or that will be collected in the spring of 2001. Only eggs which fail to hatch are collected for chemical analysis.

Because of the limited extent of this time-critical and opportunistic sampling that the Trustees will be conducting for the Stage I assessment, no Stage I Assessment Quality Assurance Project Plan was prepared. However, the sample collection and analysis will be conducted according to existing standard operating procedures. The bald eagle egg collection will be conducted in accordance with the standard operating procedures contained in Bowerman (1991) and U.S. FWS (1992). Bald eagle, great-horned owl, and red-winged blackbird eggs will be analyzed at the U.S. FWS Patuxent Analytical Control Facility or one of their contract laboratories. The facility maintains a rigorous QA/QC program for sample analysis and selects contract laboratories based on their ability to meet the QA/QC requirements. More detailed descriptions of the quality assurance program and specific standard operating procedures for analysis of PCBs and other organochlorine compounds are available upon request (see Section 5.5). More information on the Patuxent Analytical Control Facility QA/QC program and laboratory methods can be obtained from http://www.pwrc.usgs.gov/pacfhome.htm.

5.3 Pathway Evaluation

As part of the injury determination phase of the Stage I assessment, a pathway evaluation will be conducted [43 CFR § 11.63]. Natural resources, either singly or in combinations with other media, can serve as exposure pathways. For example, the resuspension of PCB contaminated sediments can result in exposure of surface water resources, floodplain soil resources, sediment resources, and biota resources downstream.

The Stage I pathway evaluation will be limited to available information for the KRE Assessment Area. As per DOI regulations, "the pathway may be determined by either demonstrating the presence of the . . . hazardous substances in sufficient concentrations in the pathway resource or by using a model that demonstrates that the conditions existed . . . such that the route served as a pathway" [43 CFR § 11.63(a)(2)].

The Stage I pathway evaluation will focus on evaluating the extent to which hazardous substances in the KRE can be attributed to releases by the PRPs and the subsequent downstream migration throughout the Kalamazoo River and into Lake Michigan. This evaluation will be based on:

- available information on releases of hazardous substances in the KRE, including from PRP facilities and from other sources
- spatial and temporal trends of hazardous substance concentrations in natural resources, including surface water and sediment, groundwater, floodplain soils, and biota
- PCB congener patterns in sediment and floodplain soils
- PCB fate and transport models (if available).

5.4 Injury Determination and Quantification

5.4.1 Surface water resources

Surface water resources are defined in the DOI regulations as including both surface water and sediments suspended in water or lying on the bank, bed, or shoreline [43 CFR § 11.14(pp)]. However, surface water resources and sediment resources are discussed separately here.

Ecosystem services provided by surface water include habitat for migratory birds, fish, benthic macroinvertebrates, and aquatic, semiaquatic, and amphibious animals; water, nutrients, and sediment transport to riparian vegetation; nutrient cycling; geochemical exchange processes; primary and secondary productivity and transport of energy (food) to downstream and downgradient organisms; growth media for aquatic and wetland plants; and a migration corridor. Human use services include drinking water, swimming, boating, industrial water supply, other water-based recreation, and assimilative capacity (i.e., the ability of a resource to "absorb low levels of [contaminants] without exceeding standards or without effects" [51 Fed. Reg. 27716, Aug 1, 1986]).

Surface water injury definitions

Based on an initial review of existing data, definitions of injury relevant to evaluation of injuries to surface water resources include the following:

- Concentrations and duration of substances in excess of drinking water standards as established by Sections 1411-1416 of the Safe Drinking Water Act (SDWA), or by other federal or state laws or regulations that establish such standards for drinking water, in surface water that was potable before the release [43 CFR § 11.62(b)(1)(i)]
- Concentrations and duration of substances in excess of applicable water quality criteria established by Section 304(a)(1) of the CWA, or by other federal or state laws or regulations that establish such criteria, in surface water that before the release met the criteria and is a committed use as habitat for aquatic life, water supply, or recreation [43 CFR § 11.62(b)(1)(iii)]
- Concentrations and duration of substances sufficient to have caused injury to ground water, air, geologic, or biological resources, when exposed to surface water; suspended sediments; or bed, bank, or shoreline sediments [43 CFR § 11.62(b)(1)(v)].

Surface water injury determination approach

The mainstem of the Kalamazoo River has been designated by Michigan for the following uses: agriculture, navigation, industrial water supply, public water supply at the point of water intake, warmwater fishery, other indigenous aquatic life and wildlife, partial body contact recreation and total body contact recreation from May 1 to October 31 (MDEQ, 1994b). Therefore, the Kalamazoo River has a designated committed use, and exceedences of applicable water quality criteria or standards constitute an injury, provided that the water met the criteria or standards prior to the release [43 CFR § 11.62(b)(iii)].

Table 5.1 lists specific regulatory criteria and standards that can be used to evaluate injury to surface waters, as defined in 43 CFR § 11.62(b)(1)(iii) and (v). Criteria include levels of PCB concentrations established to protect drinking water supplies, aquatic life, wildlife, and human health. For example, the Safe Drinking Water Act provides criteria for allowable concentrations of hazardous substances in drinking water (Table 5.1). These and other relevant threshold concentrations will be compared to measurements of hazardous substances in surface water and used to evaluate injury.

Table 5.1
Surface water criteria and standards established for total PCBs

Source	Standard or criterion (µg/L)
Safe Drinking Water Act Maximum Contaminant Level (40 CFR § 141)	0.5
Safe Drinking Water Act Maximum Contaminant Level Goal[a]	0
U.S. EPA Ambient Water Quality Criteria Chronic Value[b]	0.014
National Toxics Rule[c]	0.00017 (human cancer risk) 0.014 (aquatic life)
Great Lakes Water Quality Guidance[d]	0.000026 (human cancer risk) 0.00012 (wildlife)
Michigan Water Quality Standards Rule 323.1057[e]	0.000026 (human cancer risk) 0.00012 (wildlife)

a. U.S. EPA, 1995.
b. U.S. EPA, 1999.
c. 63 FR 61181-61196; 62 FR 42159-42208; MDEQ, 1999.
d. 62 FR 11723-11731; 62 FR 52921-52924.
e. MDEQ, 1994a.

Each of the injury definitions identified for surface water resources consists of several components. Table 5.2 summarizes the components of each definition and the conceptual approach that will be taken in assessing each component. The injury determination to be undertaken for surface water resources in this Stage I assessment will focus on an analysis of existing data using the evaluation approach presented in Table 5.2. The assessment will be conducted for Portage Creek, Kalamazoo River, and, depending on the results of the Stage I pathway evaluation, Lake Michigan.

Table 5.2
Components of relevant surface water injury definitions

Injury definition	Definition components	Evaluation approach
Water quality exceedences [43 CFR § 11.62(b)(1)(iii)]	Surface waters are a committed use as aquatic life habitat, water supply, or recreation.	Determine whether assessment area water bodies have committed uses.
	Concentrations and duration of hazardous substances are in excess of applicable water quality criteria.	Perform temporal and spatial comparisons of surface water concentrations to state and federal water quality criteria/standards.
	Criteria were not exceeded before release.	Compare pre-release conditions to state and federal water quality criteria.
Drinking water standards exceedences [43 CFR § 11.62 (b)(1)(i)]	Concentrations and duration of hazardous substances are in excess of applicable drinking water standards.	Perform temporal and spatial comparisons of surface water concentrations to state and federal standards.
	Water was potable before release.	Compare pre-release conditions to drinking water standards.
Biological resources injured when exposed to surface water/sediments [43 CFR § 11.62(b)(1)(v)]	Biological resources are injured when exposed to surface water/sediments.	Determine whether biological resources have been injured as a result of exposure to surface water/sediments.

5.4.2 Sediment resources

Ecosystem services provided by sediments include habitat for all biological resources that are dependent on the aquatic habitats in the basin. In addition, sediments contribute to services provided by surface water, including suspended sediment transport processes, security cover for fish and their supporting ecosystems, primary and secondary productivity, geochemical exchange processes, and nutrient cycling and transport.

Sediment injury definitions

Based on initial review of existing data, definitions of injuries relevant to evaluation of injuries to sediment resources include the following:

- Concentrations of hazardous substances sufficient to cause injury to biological or surface water resources that are exposed to sediments [43 CFR § 11.62(b)(1)(v); 11.62(e)(11)]

- Concentrations of PCBs sufficient to exceed the Toxic Substances Control Act (TSCA) regulations for hazardous chemical disposal of 50 mg/kg [40 CFR §761.60(a)(5)].[2]

Sediment injury determination approach

Hazardous substances in sediment can cause injury to biological resources through direct toxicity to sediment-dwelling benthic macroinvertebrates or sediment-dwelling fish and through indirect effects as a result of food-chain bioaccumulation to higher trophic level organisms. Hazardous substances in sediment can also cause injury to surface water resources that are exposed to the sediment.

Table 5.3 summarizes the approach that will be used to assess injuries to sediments. The assessment will be conducted for sediments in Portage Creek, Kalamazoo River, and, depending on the results of the Stage I pathway evaluation, Lake Michigan.

Sediment injury to benthic macroinvertebrates

To evaluate the potential for sediment hazardous substances to cause toxicity to benthic macroinvertebrates, several different regulatory agencies or research groups have developed sediment effects concentrations (SECs). These SECs are intended to provide a means of evaluating the potential for contaminated sediment to cause toxicity to sediment-dwelling aquatic biota. Examples of SECs are:

- Ontario Ministry of the Environment Guidelines for the Protection and Management of Aquatic Sediment (Persaud et al., 1993)
- U.S. EPA ARCS Program Sediment Effects Concentrations (Ingersoll et al., 1996; U.S. EPA, 1996)
- NOAA Effects Ranges (Long and Morgan, 1991)

---

2. This definition of injury is not included in the DOI regulations. However, the DOI regulations indicate that sediments are injured when hazardous substance concentrations are sufficient to cause the sediment to exhibit characteristics identified or listed pursuant to Section 3001 of the Solid Waste Disposal Act (SWDA) [43 CFR 11.62(b)(1)(iv)]. To the extent that regulations promulgated under TSCA require that sediments containing PCBs at concentrations greater than 50 mg/kg must be either incinerated or disposed in a U.S. EPA-approved chemical waste landfill, they are conceptually similar to the effect of listing under the SWDA. Moreover, the response cost incurred as a result of the TSCA guidelines (dredging restrictions, restrictions on sediment disposal) are a measure of damages.

Table 5.3
Components of relevant sediment injury definitions

Injury definition	Definition components	Evaluation approach
Biological resources injured when exposed to sediments [43 CFR § 11.62(b)(1)(v)].	Biological resources are injured when exposed to sediments.	Compare sediment concentrations to consensus-based sediment-effect concentrations developed by MacDonald et al. (2000).
	Higher trophic level organisms are injured when exposed to sediments based on bioaccumulation from the food chain.	Compare sediment concentrations to thresholds for causing injury via bioaccumulation.
Surface water resources injured when exposed to sediments [43 CFR § 11.62(b)(1)(v)].	Surface water resources are injured when exposed to sediments.	Compare sediment concentrations to thresholds for causing exceedences of surface water.
Sediment resources are injured when hazardous substance concentrations are sufficient to cause the sediment to exhibit characteristics identified or listed pursuant to Section 3001 of the Solid Waste Disposal Act (SWDA) [43 CFR § 11.62(b)(1)(iv)].	Sediment resources are injured.	Compare sediment concentrations to the 50 mg/kg TSCA threshold sediment PCB concentrations sufficient to cause the sediment to exhibit characteristics identified or listed pursuant to Section 3001 of the SWDA.

- Canadian Sediment Quality Guidelines for the Protection of Aquatic Life (Smith et al., 1996)

- Interim Criteria for Quality Assessment of St. Lawrence River sediment (Environment Canada, 1992).

All of the SECs are empirically based, relying on databases of sediment contamination and effects to invertebrates. The SECs differ in the underlying databases used, the statistical approaches employed to derive SECs from the databases, and the interpretations of the results of the statistical approaches.

MacDonald et al. (2000) developed "consensus-based" SECs for PCBs that are based on the existing SECs which have been developed by the different agencies and researchers. The consensus-based SECs were derived by estimating the central tendency of existing SECs, thereby "reconciling sediment-quality guidelines that have been developed using the various empirically based approaches" (MacDonald et al., 2000). MacDonald et al. developed three different levels of SECs for PCBs: a threshold effect concentration of 0.04 mg/kg dry weight (dw), which is intended to be the concentration below which adverse effects are unlikely; a midrange effect concentration of 0.4 mg/kg (dw), which is intended to be the concentration above which adverse effects are frequently observed; and an extreme effect concentration of 1.7 mg/kg (dw), which is the concentration above which adverse effects are usually or always observed.

Using a database of sediment contaminant concentrations and observed effects, MacDonald et al. (2000) evaluated the predictive ability of the consensus SECs in freshwater sediment. Of the samples with PCB concentrations less than the threshold effect concentration, 84% were not toxic. Of the samples with PCB concentrations greater than the midrange and extreme effect concentrations, 68% and 83%, respectively, were toxic. These data show that the consensus-based SECs are effective at predicting the toxicity of PCBs in freshwater sediments.

Sediment injury to higher trophic level organisms

In addition to causing injury to benthic macroinvertebrates, hazardous substances in sediment can also cause injury to higher trophic level organisms through bioaccumulation in the food chain. No sediment quality guidelines are available for predicting injuries through the food chain exposure route. However, threshold sediment PCB concentrations have been developed based on various models (e.g., biota sediment accumulation factors, thermodynamic equilibrium models, bioconcentration models, and food chain multiplier models; Wisconsin DNR, 1993). For example, sediment PCB threshold concentrations sufficient to cause PCB concentrations in whole fish to exceed the 0.1 mg/kg International Joint Commission objective for protection of piscivorous birds and mammals have been modeled to range from 0.0009 to 0.082 mg/kg (dw) (Wisconsin DNR, 1993). Similarly, the ecological risk assessment for the Kalamazoo River site derived sediment criteria for the protection of mink based on modeling PCBs from sediment into fish (CDM, 2000). The sediment criteria range from 0.036 to 0.1 mg/kg (dw) PCBs, depending on the modeling approach used (CDM, 2000).

Based on the quality and quantity of the existing sediment data and data on the KRE food webs, models that predict exposure to higher trophic levels based on sediment hazardous substance concentrations may be evaluated to determine the potential injury to higher trophic level organisms. In general, PCB food chain effects are predicted to occur at sediment concentrations lower than those that cause direct toxicity to benthic macroinvertebrates (Wisconsin DNR, 1993).

Sediment injury to surface water resources

Surface water may also be injured based on exposure to contaminated sediment, as contaminants can migrate from sediment to surface water. Injury to surface water occurs when sediment concentrations are sufficient to cause surface water hazardous substance concentrations to exceed relevant surface water injury criteria. For example, based on equilibrium partitioning models, a threshold sediment concentration of between 0.070 and 0.554 mg/kg (dw) is predicted to cause surface water PCB concentrations to exceed the 0.014 µg/L U.S. EPA chronic AWQC for the protection of aquatic life (Wisconsin DNR, 1993). Another possible modeling approach is to develop and use measured site-specific sediment-to-water concentration ratios (CDM, 2000). Based on the quality and quantity of the existing sediment and surface water data, models may be evaluated to determine the injury to surface water resources in the KRE resulting from contaminated sediments.

5.4.3 Groundwater resources

Groundwater resources are defined in the DOI regulations as "water in a saturated zone or stratum beneath the surface of land or water and the rocks and sediment through which ground water moves" [43 CFR § 11.14(t)].

Ecosystem services provided by groundwater include supporting habitat for terrestrial and aquatic vegetation and recharge services for surface water resources and their supporting ecosystems. Human use services include drinking water and assimilative capacity.

Groundwater injury definitions

Based on an initial review of existing data, definitions of injury relevant to evaluation of injuries to groundwater resources include the following:

- Exceedences of drinking water standards, established by sections 1411-1416 of the SDWA, or by other federal or state laws or regulations that establish such standards for drinking water, in groundwater that was potable before the release [43 CFR § 11.62(c)(i)]

- Exceedences of AWQC established by section 304(a)(1) of the CWA, or by other federal or state laws or regulations that establish such criteria for domestic water supplies, in groundwater that before the release met the criteria and is a committed use as a domestic water supply [43 CFR § 11.62(c)(iii)]

- Concentrations of hazardous substances in groundwater sufficient to have caused injury to surface water, air, geologic, or biological resources, when exposed to groundwater [43 CFR § 11.62(c)(iv)].

Groundwater injury determination approach

Groundwater injury will be evaluated by comparing hazardous substance concentrations to appropriate criteria or standards. For example, the Maximum Contaminant Level (MCL) established under Section 1416 of the SDWA for PCBs in drinking water is 0.5 μg/L [56 FR 3594]. In addition, the U.S. EPA (1995) lists PCBs as a class B2 probable carcinogen and has established a Maximum Contaminant Level Goal (MCLG) of 0 μg/L for PCBs in groundwater. The State of Michigan has also set a criterion for PCBs at the groundwater-surface water interface that is equal to the target detection limit for Aroclors, which ranges from 0.2 μg/L to 0.4 μg/L for different Aroclors (MDEQ, 1998).

Based on the quality and quantity of the existing groundwater concentration data, groundwater injuries will be evaluated using an approach similar to that described for surface water resources. The evaluation may include identification of committed uses and potability of groundwater resources, examination of concentrations and duration of hazardous substances in groundwater, and identification of exceedences of state or federal drinking water standards. Depending on the quality and quantity of data available, concentrations of hazardous substance in groundwater will also be evaluated to determine the spatial extent of injuries, delineate vertical and horizontal distribution and movements of contaminant plumes, and determine if groundwater is a significant pathway of exposure to other natural resources.

5.4.4 Geologic resources

Geologic resources are defined in the DOI regulations as "those elements of the Earth's crust such as soils, sediments, rocks, and minerals . . . that are not included in the definitions of ground and surface water resources" [43 CFR § 11.14(s)]. Geological resources in the KRE include floodplain soils.

Sediments deposited behind a number of dams are exposed, for some times of the year, as floodplain soils as a result of dam drawdown. For example, the Plainwell, Otsego, and Trowbridge dams have been removed to their sill levels, exposing approximately 507 acres of former sediments as floodplain soils (Blasland, Bouck & Lee, 1992). During high flow events in any given year, much of this floodplain may be underwater and functioning as wetland and/or riverine sediments. Overlying soils in the KRE include landfills and HRDLs where PCB contaminated waste was disposed and placed in direct contact with the soil resource.

Ecosystem services provided by floodplain soils include habitat for all biological resources that are dependent on riparian or floodplain wetland habitats in the basin. More specifically, floodplain soils provide habitat for migratory birds and mammals; habitat for soil biota; growth media and nutrients for plants; carbon storage, nitrogen fixation, decomposition, and nutrient cycling; soil organic matter and allocthonous energy to streams; hydrograph moderation; and geochemical exchange processes. Human use services include recreation (hiking, picnicking) and access corridors.

Geologic injury definitions

Based on an initial review of existing data, definitions of injury relevant to evaluation of injuries to geologic resources include the following:

- Concentrations sufficient to injure other resources, including terrestrial organisms and vegetation (e.g., toxicity), groundwater, and wildlife [43 CFR 11.62(e)].

Geological resource injury determination approach

There are no specific numeric criteria for determining when soil hazardous substance concentrations are sufficient to cause injury to exposed biological resources. The uptake, assimilation, transfer, and toxicity of soil contaminants can vary greatly from system to system. A site-specific PCB soil uptake and bioaccumulation model was developed for the KRE as part of the RI/FS ecological risk assessment (CDM, 1999). Model-derived minimum threshold values (based on estimated species-specific dietary PCB no observed adverse effects concentrations) are provided for songbirds, small terrestrial mammals, carnivorous mammals, and carnivorous birds (Table 5.4). This model, as well as any alternative models available during the course of the Stage I assessment, may be used to estimate soil PCB concentrations that are sufficient to cause injury to biota exposed to the soil.

Table 5.4
Toxicological benchmarks: PCB soil threshold concentrations for protection of wildlife

Soil PCB concentration	Protection endpoint	Reference
0.7-2.7 mg/kg	Protection of songbirds (robin)	CDM, 2000
0.8 mg/kg	Protection of small terrestrial mammals (mouse)	CDM, 1999
8 mg/kg	Protection of carnivorous mammals (fox)	CDM, 1999
0.4 mg/kg	Protection of non-piscivorous raptors (owl)	CDM, 2000
1.0 mg/kg	Protection of wildlife	U.S. DOI (as cited in U.S. EPA, 1990)
0.371 mg/kg	Based on unspecified effects in short-tailed shrew	Efroymson et al., 1997

In addition, the DOI (as cited in U.S. EPA, 1990) has recommended that soil levels of PCBs not exceed 1.0 mg/kg for the protection of wildlife (Table 5.4). However, the U.S. EPA recommends an in-depth analysis at sites where this pathway may be of particular significance (U.S. EPA, 1990). The 1.0 mg/kg recommended threshold is not specified in the DOI regulations for conducting NRDAs, and therefore an exceedence of 1.0 mg/kg PCBs in soils does not necessarily constitute injury. However, the 1.0 mg/kg U.S. DOI guideline may be used to evaluate potential injuries and the potential for floodplain soils to act as a pathway for injury to biota.

A preliminary remediation goal of 0.371 mg/kg PCBs has been established for protection of wildlife for use in risk assessments and decision making at CERCLA sites (Table 5.4; Efroymson et al., 1997). This remediation goal also is not specified in the U.S. DOI regulations for conducting NRDAs. However, the preliminary remediation goal of 0.371 mg/kg may be used to evaluate potential injuries and the potential for floodplain soils to act as a pathway for injury to biota.

The assessment will be conducted for geologic resources throughout the KRE.

5.4.5 Biological resources

Biological resources are defined in the DOI regulations as "those natural resources referred to in section 101(16) of CERCLA as fish and wildlife and other biota. Fish and wildlife include marine and freshwater aquatic and terrestrial species; game, nongame, and commercial species; and threatened, endangered, and State sensitive species. Other biota encompass shellfish, terrestrial and aquatic plants, and other living organisms" [43 CFR § 11.14(s)].

The Kalamazoo River supports a warm water fishery from Morrow Pond to its mouth at Lake Michigan, and there is a distinct difference in species composition above and below the Lake Allegan Dam. The fishery above the dam includes carp, white sucker, smallmouth bass, walleye, northern pike, channel catfish, and black crappie (J. Wesley, MDNR Fisheries Division, pers. comm., 2000). Carp and white suckers dominated the fishery until water quality improvements were made in the 1980s (Knight and Lauff, 1969; Michigan Water Resources Commission, 1972; Towns, 1984). The fishery below Lake Allegan Dam to the mouth is strongly influenced by migrating species from Lake Michigan. Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*Oncorhynchus kisutch*), steelhead (*Oncorhynchus mykiss*), brown trout (*Salmo trutta*), walleye, and lake sturgeon (*Acipenser fulvescens*) run the lower river to spawn, and the Lake Allegan Dam prevents passage of these fish to upstream areas. Stocking of salmonid species began in the early 1970s. Currently, chinook salmon, steelhead, brown trout, and walleye are stocked in the lower river (J. Wesley, MDNR Fisheries Division, pers. comm., 2000). Other game species that occur in this lower section include smallmouth bass, largemouth bass, northern pike, channel catfish, flathead catfish (*Pylodictis olivaris*), black crappie, yellow perch, and some white bass/hybrid striped bass (*Morone* sp.). Nontarget species (mainly carp, white sucker, and freshwater drum (*Aplodinotus grunniens*)) are also common in this lower river section (Knight and Lauff, 1969, Michigan Water Resources Commission, 1972; Towns, 1984; J. Wesley, MDNR Fisheries Division, pers. comm., 2000).

The majority of the Kalamazoo River corridor downstream of the city of Kalamazoo is relatively undeveloped. Riparian wetlands and floodplains are abundant and provide ample wildlife habitat for numerous wildlife species. Sections of the Kalamazoo River corridor, including the Allegan State Game Area and the private Pottawatamie Fish and Game Club, are reserved and managed specifically for wildlife resources. Wildlife known to inhabit the area include a variety of mammalian and avian species. Mammals such as red fox (*Vulpes vulpes*), raccoon (*Procyon lotor*), mink, muskrat, white-tailed deer (*Odocoileus virginianus*), woodchuck (*Marmota monax*), rabbit (*Sylvilagus floridanus*), house mice (*Mus musculus*), deer mice (*Peromyscus maniculatus* and *P. leucopus*), fox squirrel (*Sciurus niger*), and gray squirrel (*S. carolinensis*) can be found in the area, as well as resident and migratory birds such as bald eagle, great blue heron, great horned owl, red-tailed hawk, American robin (*Turdus migratorius*), American woodcock (*Scolopax minor*), ducks, and Canada geese (MDNR, 1987b).

Ecosystem services provided by fish, birds, and wildlife include prey for carnivorous and omnivorous wildlife, and nutrient and energy cycling. Human use services include various types of recreation (fishing, hunting, birdwatching) and a food source.

Biological resources injury definitions

Based on an initial review of existing data, definitions of injury relevant to evaluation of injuries to biological resources include the following:

- Concentrations of a hazardous substance sufficient to exceed action or tolerance levels established under section 402 of the Food, Drug and Cosmetic Act, 21 U.S.C. 342, in edible portions of organisms [43 CFR § 11.62(f)(1)(ii)]

- Concentrations of a hazardous substance sufficient to exceed levels for which an appropriate governmental health agency has issued directives to limit or ban consumption of such organism [43 CFR § 11.62(f)(1)(iii)]

- Concentrations of a hazardous substance sufficient to cause the biological resource or its offspring to have undergone at least one of the following adverse changes in viability: death, disease, behavioral abnormalities, cancer, genetic mutations, physiological malfunctions (including malfunctions in reproduction), or physical deformations [43 CFR § 11.62(f)(1)(i)].

An injury to biological resources can be demonstrated, per the DOI regulations, if an adverse biological response meets the following acceptance criteria [43 CFR § 11.62 (f)(2)(i-iv)]:

- The biological response is often the result of exposure to . . . [the] hazardous substances.
- Exposure to . . . [the] hazardous substances is known to cause this biological response in free-ranging organisms.
- Exposure to . . . [the] hazardous substances is known to cause this biological response in controlled experiments.
- The biological response measurement is practical to perform and produces scientifically valid results.

Biological resources injury determination approach

The injury definitions identified for biological resources consist of several components. Table 5.5 summarizes the components of each definition and the approaches that will be used by the Trustees in assessing each component. The assessment will be conducted for biological resources throughout the KRE and, depending on the results of the Stage I pathway evaluation, biological resources in Lake Michigan.

Approaches for evaluating exceedences of action or tolerance levels, state consumption advisories, and biological injuries to fish and wildlife are described below.

Table 5.5
Components of relevant biological resources injury definitions

Injury definition	Definition components	Evaluation approach
Food, Drug, and Cosmetic Act exceedences [43 CFR § 11.62(f)(1)(ii)]	Tissue concentrations of a hazardous substance in edible portions of organisms exceed applicable standards.	Compare organism tissue concentrations to applicable Food and Drug Administration (FDA) tolerances.
Consumption advisory exceedences [43 CFR § 11.62(f)(1)(iii)]	Tissue concentrations of a hazardous substance exceed levels for which a state has issued directives to limit or ban consumption.	Compile fish and bird consumption advisories and relate to concentrations of hazardous substances.
Adverse changes in viability [43 CFR § 11.62(f)(1)(i)]	The biological resource or its offspring has undergone adverse changes in viability.	Review site-specific field and laboratory studies on adverse effects; compare site exposure data to toxicological data; evaluate causality.

Exceedences of action or tolerance levels

Regulations promulgated pursuant to the federal Food, Drug and Cosmetics Act (Section 402, 21 U.S.C. 342) and fish consumption guidelines established by the Michigan Department of Public Health (MDPH)[3] set an action or tolerance level of 2 mg/kg total PCBs in edible portions of fish tissue. In addition, FDA regulations (Section 402, 21 U.S.C. 342) also establish an action or tolerance level of 3 mg/kg PCB in poultry (fat basis) [21 CFR § 109.30].

To evaluate the potential injury to fish and wildlife in the KRE based on exceedences of action or tolerance levels, the Trustees will compare the appropriate federal and state action or tolerance level to fish fillets of recreational and commercial fish species and to edible portions of wildlife hunted recreationally, including waterfowl (ducks and geese).

Consumption advisories

The State of Michigan has issued fish consumption advisories for the Kalamazoo River and Portage Creek (Table 5.6; Michigan Department of Community Health, 2000). These fish consumption advisories either restrict consumption or recommend no consumption for specific species of fish found in sections of the river or creek. Two types of consumption advisories are issued: one for the general population and the other for women and children. The consumption advisory for women and children is more restrictive and is meant for women of childbearing age and children under 15.

To evaluate consumption advisories for fish and waterfowl in the KRE, the Trustees will gather and analyze available information on consumption advisories for all relevant time periods, and evaluate the State's procedures for establishing the advisories.

Biological injuries

Biological injuries include those injuries that adversely affect the viability of aquatic and terrestrial biota [43 CFR § 11.62(f)(1)(i)]. Biological injuries to aquatic biota may be assessed in aquatic invertebrates, fish, reptiles, amphibians, waterfowl, and aquatic or semi-aquatic mammals. The following injury categories may be assessed by the Trustees: death, disease, cancer, physiological malfunctions (including reproduction), developmental effects (reduced growth), and physical deformities. PCBs have been documented to cause these types of adverse effects in fish and wildlife exposed to PCBs (e.g., Eisler, 1986; Peterson et al., 1993; Safe, 1994).

3. As of April 1, 1996, pursuant to Executive Order 1996-1, the functions of the Michigan DPH were divided among the Michigan DEQ, the Commerce Department, and the Department of Community Health.

Table 5.6
Fish consumption advisories issued by Michigan for the Kalamazoo River and Portage Creek because of elevated concentrations of PCBs

River section	Species	Consumption advisory
Kalamazoo River (from Battle Creek to Morrow Pond dam)	Carp	Do not eat fish.
Kalamazoo River (from Morrow Pond Dam to Lake Allegan Dam) and Portage Creek (below Monarch Mill Pond)	Carp, catfish, suckers	Do not eat fish.
	Largemouth and smallmouth bass	Do not eat fish greater than 14 inches long.
	All other species	General population should limit consumption to one meal per week. Women and children[a] should not eat these fish species.
Kalamazoo River (below Lake Allegan Dam)	Carp, catfish	Do not eat fish
	Largemouth and smallmouth bass	General population should limit consumption to one meal per week for fish greater than 14 inches long. Women and children should not eat fish greater than 14 inches long.
	Northern pike	Do not eat fish greater than 22 inches long
	All other species	General population have unlimited consumption of these fish species. Women and children should limit consumption to one meal per month.

a. Women of childbearing years and children less than 15.

Source: Michigan Department of Community Health, 2000.

Site-specific data on adverse effects to biological resources will be compiled and reviewed. In addition, site data (or models, if appropriate) on the exposure of biota to PCBs will be compared to toxicity reference values obtained from the literature. The May 2000 Preassessment Screen contains examples of such toxicity reference values (Stratus Consulting, 2000).

5.5 Procedures for Sharing Data

The DOI NRDA regulations state that an assessment plan includes:

- procedures and schedules for sharing data, split samples, and results of analyses, when requested, with any identified potentially responsible parties and other natural resource Trustees [43 CFR § 11.31(a)(4)].

To facilitate the data-sharing process, PRPs and other state or federal agencies will be provided with an opportunity, as deemed appropriate, to obtain a copy of the database(s) used in the Stage I assessment. If PRPs or state or federal agencies wish to receive such data, a written request identifying the data desired should be submitted to:

Lisa L. Williams
U.S. Fish and Wildlife Service
2651 Coolidge Road, Suite 101
East Lansing, MI 48823.

The Trustees will provide the data to the PRPs and any other interested parties once the data have been validated and are available.

6. Stage I Damage Determination

This chapter describes the Trustees' approach for conducting the Stage I damage determination. Section 6.1 provides an overview of the approach that will be used by the Trustees in the Stage I assessment. Section 6.2 describes the approach for the Stage I restoration planning and costing, and Section 6.3 describes the approach for the Stage I determination of compensable values. Section 6.4 describes the relationship between the NRDA damage determination and the response actions being conducted as part of the ongoing RI/FS.

6.1 Overview

The purpose of a damage determination is to "establish the amount of money to be sought in compensation for injuries to natural resources resulting from a . . . release of a hazardous substance" [43 CFR § 11.80(b)]. The DOI regulations define the measure of damages as *restoration costs* plus, at the discretion of the Trustees, *compensable values for interim losses* [43 CFR § 11.80(b)]. Restoration costs are the costs of restoration actions that restore the injured resources and services[1] to baseline, which is the condition that would have existed had the hazardous substance release(s) not occurred [43 CFR §11.14(e)]. Restoration actions can include actions to restore, rehabilitate, replace, or acquire the equivalent of the injured resources and services they provide [43 CFR § 11.80(b)]. Compensable values for interim losses are "the value of lost public use of the services provided by the injured resources" [43 CFR § 11.83(c)(1)] and can include both past losses and losses that will occur until the injured resources and services are returned to baseline. Thus, the total amount of NRDA damages includes both the cost of restoration to baseline and the compensable values for interim losses. All recovered damages will be used by the Trustees for environmental restoration.

The NRDA damage determination process is distinct and separate from the ongoing RI/FS work being conducted by MDEQ, U.S. EPA, and the PRPs. The NRDA and RI/FS processes address different aspects of the PCB contamination problem in the KRE. The purpose of the RI/FS is to provide information for selection of a remedy that "prevent[s] or minimize[s] the releases of hazardous substances so that they do not migrate to cause substantial danger to present or future public health or welfare or the environment" [CERCLA § 101(24), 42 U.S.C. 9601]. Remedial actions often involve source control measures or measures to reduce risk from exposure to hazardous substances. The purpose of NRDA is to restore resources and services to baseline conditions, and recover damages for interim losses and apply those damages to restoration. For

1. Natural resource services are defined as the "physical and biological functions performed by the resource, including the human uses of those functions" [43 CFR § 11.14(nn)]

example, NRDA restoration actions can include extraction or containment of contaminated sediment/soil to shorten the return to baseline or to reduce the interim losses, as well as other types of restoration actions to address injuries to natural resources (e.g., habitat restoration, species management programs, actions to increase human use or enjoyment of the resources). Therefore, both processes address the problems caused by the hazardous substance releases into the KRE, but they differ in their objective, methods, and outcome.

The Trustees will consider two types of restoration actions in the Stage I assessment:

- *Sediment/soil restoration.* To the extent that on-site actions, including extraction or containment of contaminated sediment and soils, are necessary to accelerate the return of injured resources and services to baseline, the Trustees will evaluate such actions as potential restoration actions.
- *Ecosystem-based restoration.* Ecosystem-based restoration actions can restore resources and/or services that are similar to, but not the same as, those that are injured. Examples of such restoration actions could include habitat restoration or enhancement, stocking programs, species management programs, or improvements in the public's ability to use or enjoy resources.

As described in Section 6.2, the Stage I restoration planning effort will identify specific types of potential restoration actions (within the two general types listed above) and estimate the costs of their implementation.

The value of lost recreational fishing services will be an important component of the interim loss compensable value determination, as described in Section 6.3. The compensable values of other losses, including other types of recreation and other active uses (e.g., aesthetics, land use) may also be considered.

6.2 Restoration Planning

The purpose of the Stage I restoration planning is to identify the types and amount of preferred restoration actions and to estimate the costs of their implementation. Two general types of restoration actions will be considered: sediment/soil restoration and ecosystem-based restoration.

6.2.1 Sediment/soil restoration

To the extent that PCBs are causing injuries to natural resources, eliminating or reducing exposure of the injured resources to PCBs can restore the resources to baseline (i.e., the condition they would have been in had the PCB releases not occurred). Thus, actions to extract or contain PCB contamination, such as sediment dredging or capping, soil removal or capping, or riverbank stabilization, will be evaluated by the Trustees as a potential approach to restoring injured resources to baseline. However, such sediment/soil restoration actions to address PCB contamination cannot compensate for interim losses.

Sediment/soil restoration actions would be in addition to and coordinated with the PCB cleanup that will be selected for the site remedial action. The MDEQ and U.S. EPA, in conjunction with the responsible parties at the site, are conducting a RI/FS for the site. The purpose of the RI/FS is to provide information for making a decision regarding PCB cleanup actions as part of the site remedy. To the extent that additional actions involving PCB-contaminated sediment and/or soil would return the injured resources and services to baseline, and may be justified when considered among a range of restoration options, the Trustees will consider such additional actions as part of the Stage I restoration planning process. The Trustees will conduct an evaluation of the PCB injuries that would remain after implementation of the remedial action, and will consider whether additional removal or other actions involving contaminated sediment or soil would reduce those injuries and thereby speed the return to baseline conditions.

6.2.2 Ecosystem-based restoration

A second type of restoration action that the Trustees will consider is ecosystem-based restoration. The DOI's NRDA regulations emphasize the restoration of natural resource to baseline, as measured by their services. Services are defined as:

> The physical and biological functions performed by the resource. . . . These services are the result of the physical, chemical, or biological quality of the resource [43 CFR §11.14(nn)].

The DOI regulations also state that:

> Services include provision of habitat, food and other needs of biological resources . . . flood control, ground water recharge, waste assimilation, and other such functions that may be provided by natural resources [43 CFR §11.71(e)].

In the KRE, the services provided by different components of the ecosystem are inextricably linked to each other. For example, KRE floodplain soils, floodplain vegetation, and river geomorphology interact to:

- stabilize streambanks through anchoring of the soil by plant root structures, dissipate erosive stream energy, and maintain channel geometry

- control surface water/groundwater exchange rates and influence areas of groundwater discharge or recharge
- control sediment delivery rates to downstream aquatic and riparian resources
- serve as an important carbon source for the river ecosystem and provide a growth medium for plants and substrate for nutrient cycling and decomposition
- provide key habitat for vegetation, fish, and migratory birds and mammals
- provide cover and food for fish and benthic invertebrates, shade the water from solar radiation, contribute to aquatic physical habitat complexity through addition of large woody debris and root masses, and regulate the supply of nutrients to the aquatic ecosystem
- provide critical connectivity among upland and aquatic habitats and a corridor for upstream and downstream dispersal for plant and animal species.

This linkage between different resources, their functions, and services necessitates an ecosystem-based approach toward restoration planning. Only through considering the interdependencies of the different resources and their services can restoration actions achieve the long-term restoration of the lost resource services in a cost-effective manner.

An ecosystem-based approach toward restoration at the KRE has several implications for the restoration planning process. First, the approach necessitates consideration of multiple types of restoration actions to address services lost because of hazardous substance injuries. The hazardous substances that have been released into the KRE are one of several ecological stressors on the system. Other stressors such as habitat loss or degradation, alterations in natural hydrologic processes, and nonpoint source pollution can also result in loss of resources or services similar to the losses caused by hazardous substance releases. Therefore, to restore KRE resources and services injured by hazardous substances, the Trustees will consider types of restoration activities that address these other stressors. Such restoration activities could include preserving and/or restoring floodplain, wetland, or riverine habitat, restoring the natural river flow patterns, or implementing best management practices in the basin to control nonpoint source runoff. The PRPs may not be liable under CERCLA for the effects caused by these other stressors, but actions to address those effects may be one means to restore resource services lost or impaired by the hazardous substance releases for which the PRPs are responsible.

Second, an ecosystem-based approach toward restoration planning also necessitates an ecosystem-based approach toward evaluating the ecological losses associated with Superfund response actions. Some response actions may incur "collateral" injuries on ecological resources in the KRE. For example, extensive sheet piling of riverbanks can channelize river flow, restrict natural flood regimes, and alter the connectivity between the river and its riparian corridor. The Stage I restoration planning phase will evaluate and consider potential long-term ecological impacts of the response actions when determining the type and amount of restoration needed.

The Trustees will conduct the identification and selection of Stage I restoration alternatives in the context of and consistent with long-term ecological management goals for the KRE. NRDA restoration actions must be consistent with the long-term goals for the KRE for the restoration to be both long-lasting and effective at making the public whole. Restoration actions that do not take into account the long-term ecological management goals for the site may be counterproductive by providing services that are inconsistent with the needs of resource managers and the public. Such actions may also be short-lived if they ignore the ecological and hydrological realities of the site. Therefore, the restoration planning will be conducted in close coordination with appropriate resource managers and within the context of long-term ecological goals for the KRE.

6.2.3 Restoration planning activities

Figure 6.1 depicts the Stage I restoration planning activities for the KRE site. First, the Trustees will develop a list of potential restoration actions. This list will rely heavily on restoration proposals or ideas already developed for the KRE by resource managers. The list will include a variety of types of projects that have the potential to restore the range of KRE resources and services. The Trustees will then develop criteria that will be used to evaluate the list of potential projects. The criteria will be based on factors identified in the DOI NRDA regulations [43 CFR § 11.82(d)], on Trustee agency priorities and mandates, and on an ecosystem-based perspective, as described above. The criteria may include such factors as:

- ***Project acceptability.*** A project must comply with the requirements of the DOI NRDA regulations and with applicable and relevant laws.
- ***Project focus.*** The degree to which a project meets the goals and objectives of the Trustees for restoration of the KRE is an important factor.
- ***Project feasibility.*** A project must be technically and administratively feasible and cost-effective.
- ***Project benefits.*** The types, timing, and permanence of benefits provided by a project will be considered by the Trustees in the context of the types and timing of the resources and services lost and the ecosystem perspective toward restoration.

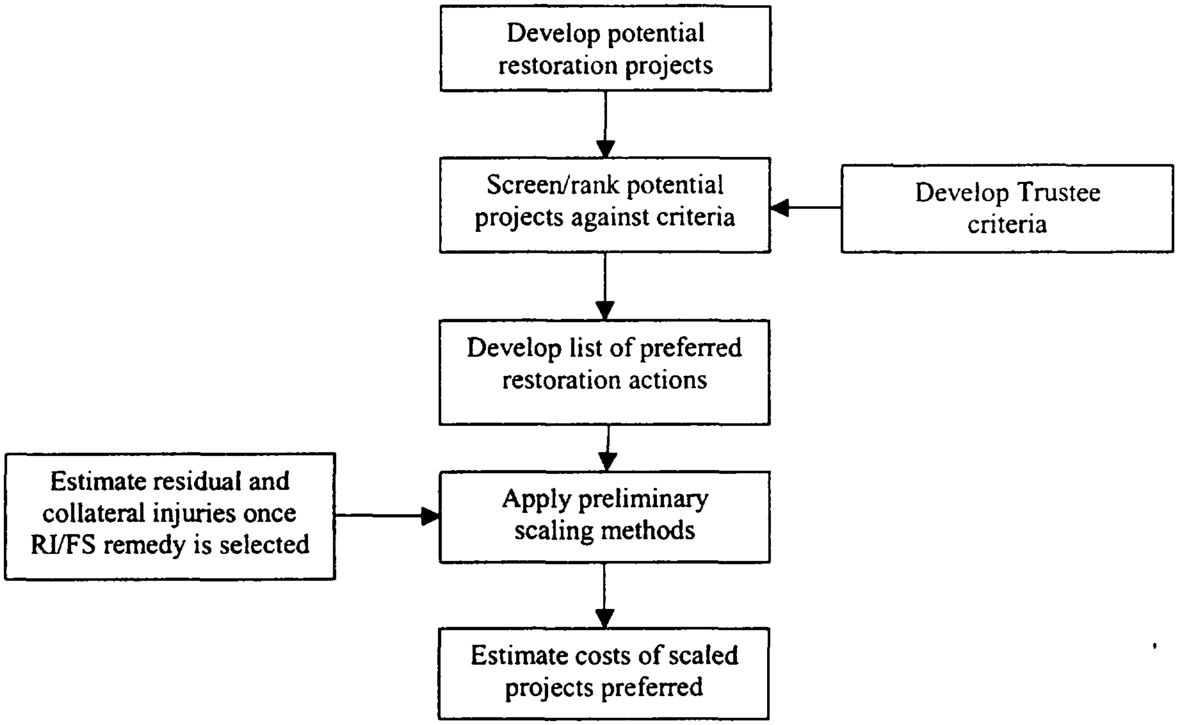

Figure 6.1. Process for identifying, selecting, and costing preferred restoration alternatives.

The list of potential projects will be evaluated using the criteria to provide a short list of preferred restoration alternatives or classes of alternatives. The Trustees anticipate developing a range of alternatives [43 CFR § 11.82(c)] that may include actions such as habitat restoration or enhancement, resource acquisition, species management programs, or enhancements to human use or enjoyment of the resource.

The range of preferred restoration alternatives will then be scaled using preliminary scaling techniques. Scaling is the process of determining the appropriate amount of restoration that is required. Since the appropriate methods for scaling depend on several factors, including the types and magnitude of injuries and service losses and the types of restoration projects being considered, the Trustees cannot at this time specify the scaling methods that will be used in the Stage I assessment. However, the methods (or combinations thereof) used for restoration project scaling will estimate the baseline level of services and the level of services generated by potential restoration actions.

As part of the Stage I restoration planning effort, the Trustees may conduct limited on-site interviews to obtain insight on public opinions about restoration strategies. The intent of these interviews will be to provide information for determining subsequent restoration directions. Interview responses will contain information about public preferences regarding different restoration options.

The Trustees will also develop cost estimates for implementing the preferred and scaled restoration projects. Cost estimates will include both direct and indirect costs of implementing the preferred alternatives [43 CFR § 11.83(b)(1)]. Direct costs are those that are directly associated with the implementation of the restoration alternative, such as compensation of employees, cost of materials acquired, consumed, or expended specifically for the purpose of the action, equipment and other capital expenditures, and other costs expected to be incurred [43 CFR § 11.83(b)(1)(i)]. Indirect costs include costs such as overhead [43 CFR § 11.83(b)(1)(ii)]. The exact methods that will be used to estimate costs depend on the nature of the preferred restoration alternatives [43 CFR § 11.83(b)(2)]. The cost estimates will be used in the overall Stage I quantification of damages.

6.3 Compensable Value Determination

Compensable values for interim losses are the dollar values of the resources and services lost because of the hazardous substance releases. In the Stage I damage determination, the Trustees will use existing information, supplemented by limited new site-specific data collection efforts, to assess compensable values for interim losses. To the extent that more technical and comprehensive analyses can subsequently be undertaken cost-effectively, the compensable value determination may be refined in Stage II.

The Trustees will identify the types of potential damages that are likely to be occurring in the KRE (e.g., recreational fishing, wildlife viewing, dredging or dam removal restrictions). The damage categories quantified in the Stage I assessment will depend on the availability and applicability of existing data. The computation of compensable recreational fishing damages will be a major component of this evaluation.

The evaluation of compensable values for interim losses will be based largely on the benefits transfer approach. Rather than focusing on collecting new primary valuation data, benefits transfer involves estimating damages for the KRE and its circumstances by using values derived from the application of primary economic research methods in other studies at the same or similar sites for the same or similar circumstances. Using already existing (secondary) data for similar areas and similar types of services and resource injuries results in a cost-effective, first-order estimate of damages.

A benefits transfer approach identified in the U.S. DOI regulations, the "unit value" method, will be applied in this evaluation [43 CFR § 11.83(c)(2)(vi)]. For recreational direct use values, for example, the unit value method requires selecting a unit value for the direct use being measured and multiplying it by the number of units lost or impaired as a result of natural resource injuries (e.g., the value of a fishing day multiplied by the number of fishing days lost or impaired). Thus, the unit value method can be used to value not only lost use (including use substituted to other recreational sites) but also the reduction in the quality of use that continues to occur under the current, injured conditions.

To guide the selection of valuation studies for use in the benefits transfer approach, the Stage I assessment will focus on results from studies in and around the KRE and the Great Lakes, and from studies investigating fish consumption advisories (FCAs). An extensive body of literature exists that estimates the value of services lost because of FCAs and reports attitudes toward and behavioral changes as a result of FCAs. Such information will be useful in benefits transfer analysis.

Some limited site-specific data will be used to augment and fortify the benefits transfer analysis. For example, the PRPs have collected and made available data on fishing activity and FCA awareness for 690 anglers residing near the Kalamazoo River basin (Atkins, 1994). An analysis of the Atkins (1994) data set will be performed to understand its contents, strengths, weaknesses, applicability, and conclusions. If appropriate, these data will also be used to identify unique or important aspects of the fishery, and the uniqueness of the site versus the availability of good, proximate substitutes. Other information on the site will also be carefully reviewed as it becomes available to gain an understanding of services and values.

In addition, a statewide recreation demand model is being developed by Michigan State University (MSU) for the State of Michigan. The purpose of the MSU model is to value recreational resources based on observed user behavior as a function of site characteristics and travel costs. The MSU model will be capable of evaluating how recreationists respond to incremental changes in environmental characteristics and their values for such changes, although it is unclear at this time to what extent the model will be directly applicable to the KRE compensable damage determination.

If the MSU model is completed within the time frame of this Stage I assessment, the Trustees will evaluate the model to ascertain its usefulness to support the Kalamazoo NRDA and the overall damage estimate. The use of travel cost methods such as this model is identified in the NRDA regulations as an appropriate valuation method for determining compensable value [43 CFR § 11.83(c)(2)(iv)]. Additional modeling efforts using the model and its data set may be warranted if useful scenarios are possible. Regional values produced by the model may be relevant in calibrating or corroborating benefits transfer results.

Finally, the Trustees will conduct limited interviews with local residents, consisting primarily but not exclusively of anglers and including anglers who fish and who do not fish the Kalamazoo River. These interviews can be used to obtain a variety of detailed information, including recreational trip records and avidity levels, substitution patterns, socioeconomic characteristics, awareness of and attitudes toward FCAs, preferences over different sites, and opinions about the Kalamazoo River. The interviews will provide insight into the impacts of FCAs at the site beyond what is captured in existing data. Results from these interviews will be used to analyze the link between natural resource injuries and their impact on human use service flows, and can be used to validate the benefits transfer estimates of damages.

In the Stage I assessment, sensitivity analysis will be done to address uncertainties in the benefits transfer assumptions [43 CFR § 11.84(d)]. The quality and quantity of substitute sites in the KRE will be given consideration [43 CFR § 11.84(f)]. Measures to guard against double counting and recovery will be incorporated in combining different methods and approaches to estimate value [43 CFR § 11.36(a)(2) and 11.84(c)]. Finally, annual losses will be compounded and discounted to aggregate damages following the guidance in the regulations [43 CFR § 11.84(f)].

6.4 Relationship to the RI/FS Process

A key feature of the relationship between the RI/FS remedy and the NRDA is that the NRDA damage amount is related to the timing, type, and amount of remediation selected from the RI/FS. For example, if a no-action or minimal remedy is selected, then the total amount of lost natural resource services that requires restoration actions will be larger, and the compensable value losses will be larger. Similarly, if the remedy itself results in a loss of resources or services, then additional restoration would be required to compensate the public for these losses.

Because of this relationship, information generated during the NRDA can be beneficial to the RI/FS, and vice versa. The Stage I assessment is being timed to provide useful information to the remedial action decision-makers by evaluating both potential residual injuries (PCB-caused injuries remaining after the selected remedy is implemented) and collateral injuries (injuries resulting from the remedy itself) under different remedial alternatives. This information may help the decision-makers evaluate the overall protection of human health and the environment and the long-term effectiveness of different remedial alternatives. At the same time, the Stage I damage determination cannot be concluded until a remedy for the site is selected, since the type and magnitude of the remedy affects the type and magnitude of restoration that is required to make the public whole. Therefore, information generated as part of the Stage I assessment that is potentially useful to the remedial decision-makers will be provided to them. This exchange of information will help ensure meaningful and useful coordination between the RI/FS and the NRDA.

References

Abramowicz, D.A., M.J. Brennan, H.M.V. Dorf, and E.L. Gallagher. 1993. Factors influencing the rate of polychlorinated biphenyl dechlorination in Hudson River sediments. *Environmental Science and Technology* 27:1125-1131.

Atkins, C. 1994. Kalamazoo River Anglers Survey. Prepared by Michigan State University for the Kalamazoo River Study Group of PRPs.

Bhaskar, R.D., I.J. Brink, and B. Vande Wege. 1983. Distribution of Polychlorinated Biphenyls and Dieldrin in Kalamazoo River Sediments. Paper presented at the 87th Annual Meeting of the Michigan Academy of Arts and Sciences. March.

Blasland, Bouck & Lee. 1992. Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Description of the Current Situation. Prepared by Blasland & Bouck, Engineers and Scientists, Syracuse, NY, for the Kalamazoo River Study Group. July.

Blasland, Bouck & Lee. 1993a. Allied Paper, Inc. Operable Unit Remedial Investigation/Focused Feasibility Study Work Plan. July.

Blasland, Bouck & Lee. 1993b. King Highway Landfill Operable Unit Remedial Investigation/Focused Feasibility Study Work Plan. July.

Blasland, Bouck & Lee. 1994a. Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Remedial Investigation/Feasibility Study. Draft Technical Memorandum 14. Biota Investigation. Volumes I-VI.

Blasland, Bouck & Lee. 1994b. Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Remedial Investigation/Feasibility Study. Technical Memorandum 6. King Highway Landfill Operable Unit. Volumes I-III. March.

Blasland, Bouck & Lee. 1994c. Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Remedial Investigation/Feasibility Study. Draft Technical Memorandum 7. Allied Paper, Inc. Operable Unit. Volumes I-VII. March.

Blasland, Bouck & Lee. 1994d. Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Remedial Investigation/Feasibility Study. Draft Technical Memorandum 12. Former Impoundment Sediment and Geochronologic Dating Investigation. Volumes I-IV. May.

Blasland, Bouck & Lee. 2000. Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site Remedial Investigation/Feasibility Study. Technical Memorandum 11. Allied Paper, Inc. Operable Unit. Biota and Surface Water Investigations and Wetlands Assessment. Volume 1 of 3. May.

Bowerman, W.W. 1991. Standard Operating Procedure for Bald Eagle Handling, Measuring, Blood and Feather Collection. Michigan State University Aquatic Toxicology Laboratory SOP No. MSU/ATL-BAEA-01.

Brown, J.F. and R.E. Wagner. 1990. PCB movement, dechlorination, and detoxication in the Acushnet estuary. *Environmental Toxicology and Chemistry* 9:1215-1233.

Brown, J.F., R.E. Wagner, H. Feng, D.L. Bedard, M.J. Brennan, J.C. Carnahan, and R.J. May. 1987. Environmental dechlorination of PCBs. *Environmental Toxicology and Chemistry* 6:579-593.

Carr, R.A., R.L. Durfee, and E.G. McKay. 1977. PCBs Involvement in the Pulp and Paper Industry. Prepared by Versar, Inc., Springfield, VA, for the U.S. EPA, Washington, DC. February.

CDM. 1993. Biota Sampling Plan for the Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site. October.

CDM. 1999. Final Draft: Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site. Ecological Risk Assessment. Prepared by Camp Dresser & McKee, Detroit, MI. April.

CDM. 2000. Addendum: Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site. Ecological Risk Assessment. August.

Eastern Research Group. 1999. Report on the Peer Review of the Data Evaluation and Interpretation Report and Low Resolution Sediment Coring Report for the Hudson River PCBs Superfund Site. Prepared for the U.S. Environmental Protection Agency, Region 2, New York, by Eastern Research Group, Inc. June 3.

Efroymson, R.A., G.W. Suter II, B.E. Sample, and D.S. Jones. 1997. Preliminary Remediation Goals for Ecological Endpoints. ES/ER/TM-162/R2. Prepared by the U.S. Department of Energy by Lockheed Martin Energy Systems, Inc. Oak Ridge National Laboratory.

Eisler, R. 1986. Polychlorinated biphenyl hazards to fish, wildlife, and invertebrates: A synoptic review. *U.S. Fish and Wildlife Service Biological Report* 85(1.7).

Environment Canada. 1992. Interim Criteria for Quality Assessment of St. Lawrence River Sediment. St. Lawrence Action Plan. July.

Environmental Resources Management. 1989. Letter Report Soil Investigation, Georgia-Pacific Facility, August. Prepared for Georgia-Pacific Corporation, Kalamazoo, MI. October.

Erickson, M.D. 1997. *Analytical Chemistry of PCBs*. Lewis Publishers, New York.

Flanagan, W.P. and R.J. May. 1993. Metabolite detection as evidence for naturally occurring aerobic PCB biodegradation in Hudson River sediments. *Environmental Science and Technology* 27:2207-2212.

FTC&H. 1991. Analysis of Soil Samples taken from the Kalamazoo River. Prepared by Fishbeck, Thompson, Carr & Huber, Inc. May.

Geraghty and Miller. 1994. Test Pit Investigation Technical Memorandum, 12th Street Landfill Operable Unit, Plainwell, Michigan. Allied Paper, Inc./Portage Creek/Kalamazoo River Superfund Site. Submitted to Environmental Response Division, MDNR, by Simpson Plainwell Paper Company. February.

GZA/Donohue. 1988. Technical Memoranda. Sampling for PCB Contamination Kalamazoo River: Morrow Lake, Comstock, Michigan. Prepared for MDNR, Surface Water Quality Division. September.

GZA/Donohue. 1990. Evaluating Sediment Burial Rates and PCB Partition Coefficients, Kalamazoo River, Michigan. Prepared for MDNR, Surface Water Quality Division. June.

Horvath, F.J. 1984. PCBs in Fish, Sediments, and Water of the Lower Kalamazoo River and Nearby Lake Michigan. Prepared for U.S. EPA, Great Lakes National Program Office, Chicago, IL. January.

Ingersoll, C.G., P.S. Haverland, E.L. Brunson, T.J. Canfield, F.J. Dwyer, C.E. Henke, N.E. Kemble, D.R. Mount, and R.G. Fox. 1996. Calculation and evaluation of sediment effect concentrations for the amphipod *Hyalella azteca* and the midge *Chironomus riparius*. *Journal of Great Lakes Research* 22(3):602-623.

International Joint Commission. 1989. Great Lakes Water Quality Agreement of 1978, Revised. International Joint Commission of United States and Canada. September.

Knight, A.W. and G.H. Lauff. 1969. Water Quality Studies on the Kalamazoo River. Prepared at Michigan State University, Institute of Water Research. Technical Report No. 5. September.

Limno-Tech. 1987. Results of Allied Paper Program to Monitor for PCBs: 1985-1986. Linmo-Tech, Inc., Ann Arbor, MI. April.

Long, E.R. and L.G. Morgan. 1991. The Potential for Biological Effects of Sediment-Sorbed Contaminants Tested in the National Status and Trends Program. National Oceanic and Atmospheric Administration Technical Memorandum NOS OMA 52. August.

MacDonald, D.D., L.M. Dipinto, J. Field, C.G. Ingersoll, E.R. Long, and R.C. Swartz. 2000. Development and evaluation of consensus-based sediment effect concentrations for polychlorinated biphenyls. *Environmental Toxicology and Chemistry* 19:1403-1413.

MDEQ. 1994a. Natural Resources and Environmental Protection Act 451, Part 31, Part 4, R 323.1057 Toxic Substances, as amended. http://www.deq.state.mi.us/swq/rules/part4.html. Accessed November 2, 2000.

MDEQ. 1994b. Natural Resources and Environmental Protection Act 451, Part 31, Part 4, R 323.1100 Designated Use, as amended. http://www.deq.state.mi.us/swq/rules/part4.html. Accessed November 2, 2000.

MDEQ. 1998. Part 201 Op Memo 6, Revision 5. November 16.

MDNR. 1983. A Survey of PCBs in the Kalamazoo River and Portage Creek Sediments, Kalamazoo to Lake Allegan, 1983. Prepared by MDNR, Surface Water Quality Division. November.

MDNR. 1984. Kalamazoo River PCB Problem. Memorandum from W. Creal, Surface Water Quality Division, to A. Bloomer, Michigan Department of Public Health. April. 2 pp.

MDNR. 1986. Georgia Pacific Waste Disposal Ponds. Interoffice Communication from W. Creal, Great Lakes and Environmental Assessment Section, to F. Morley, Compliance Section #1. December. 5 pp.

MDNR. 1987a. Allied Paper, PCB. Interoffice Communication from G. Kilmer, Groundwater Quality Division, to R. Johns, Chief. February. 2 pp.

MDNR. 1987b. Kalamazoo River Remedial Action Plan. Second Draft. Prepared by Michigan Department of Natural Resources, Lansing, MI. December.

MDNR. 1990. A Qualitative Biological Survey of Kalamazoo River, near Battle Creek, Michigan (Calhoun and Kalamazoo Counties), July 7, 1988. Staff Report. Prepared by MDNR, Surface Water Quality Division. March.

MDNR. 1991. Sediment Sampling Data from Kalamazoo River. Prepared by MDNR, Environmental Laboratory. November. 3 pp.

MDNR. 1992. STORET Water Quality System data.

MDPH. 1990. Analyzed Test Results on 11 Waterfowl Tissue Samples. Attached to letter from J.L. Hesse, Environmental Health Assessment Division, to T.J. Kubiak, U.S. Fish and Wildlife Service. October.

Mehne, C. 1994. Unpublished Data on Contaminant Concentrations in Bird Eggs Collected from Kalamazoo River Corridor. From Dr. C. Mehne, Kalamazoo, MI.

Michigan Department of Community Health. 2000. Michigan 2000 Fish Advisory. <http://www.mdch.state.mi.us/pha/fish/> Accessed 8/3/00.

Michigan Water Resources Commission. 1972. Biological Survey of the Kalamazoo River, June-August, 1971. April.

Michigan Water Resources Commission. 1973. Polychlorinated Biphenyl Survey of the Kalamazoo River and Portage Creek in the Vicinity of the City of Kalamazoo, 1972. January.

Persaud, D., R. Jaagumagi, and A. Hayton. 1993. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Prepared by Ontario Ministry of the Environment and Energy. August.

Peterson, R.E., H.M. Theobald, and G.L. Kimmel. 1993. Developmental and reproductive toxicity of dioxins and related compounds: Cross-species comparisons. *Critical Reviews in Toxicology* 23:283-335.

Rhee, G.-Y., R.C. Sokol, C.M. Bethoney, and B. Bush. 1993a. Dechlorination of polychlorinated biphenyls by Hudson River sediment organisms: Specificity to the chlorination pattern of congeners. *Environmental Science and Technology* 27:1190-1192.

Rhee, G.-Y., B. Bush, C.M. Bethoney, A. DeNucci, H.-O. Oh, and R.C. Sokol. 1993b. Reductive dechlorination of Aroclor 1242 in anaerobic sediments: Pattern, rate and concentration dependence. *Environmental Toxicology and Chemistry* 12:1025-1032.

Roy F. Weston, Inc. 1994. Analytical Report (Revised). Kalamazoo River Mammal Study, Kalamazoo, MI. Prepared for U.S. EPA/ERT. June. 253 pp.

Safe, S.H. 1994. Polychlorinated biphenyls (PCBs): Environmental impact, biochemical and toxic responses, and implications for risk assessment. *Critical Reviews in Toxicology* 24:87-149.

Smith, S.L., D.D. MacDonald, K.A. Keenleyside, C.G. Ingersoll, and L.J. Field. 1996. A preliminary evaluation of sediment quality assessment values for freshwater ecosystems. *Journal of Great Lakes Research* 22(3):644-638.

Sokol, R.C., C.M. Bethoney, and G.-Y. Rhee. 1998. Effect of Aroclor 1248 concentration on the rate and extent of polychlorinated biphenyl dechlorination. *Environmental Toxicology and Chemistry* 17:1922-1926.

Sokol, R.C., O.-S. Kwon, C.M. Bethoney, and G.-Y. Rhee. 1994. Reductive dechlorination of polychlorinated biphenyls in St. Lawrence River sediments and variations in dechlorination characteristics. *Environmental Science and Technology* 28:2054-2064.

Stratus Consulting. 2000. Preassessment Screen. Kalamazoo River Environment Site, Michigan. Prepared by Stratus Consulting Inc. for the Michigan Department of Environmental Quality, Michigan Department of the Attorney General, U.S. Fish and Wildlife Service, and National Oceanic and Atmospheric Administration. May.

STS Consultants. 1989. Groundwater Modeling Evaluation to Determine Production Well Influence on the Aquifer Beneath the James River Landfill Facilities in Parchment, Michigan — STS Project No. 16684XF. Letter attached from Vladimir Wojnar and Richard K. Lowe, STS Consultants Ltd., to Victor R. Ferguson, James River Corporation, Parchment, MI. February.

Swanson Environmental. 1987. Site Investigation Willow Boulevard Landfill. Prepared for Georgia-Pacific Corporation, Kalamazoo, MI.

Swanson Environmental. 1990. "A" Site Investigation, Kalamazoo, Michigan. Prepared for Georgia-Pacific Corporation, Kalamazoo, MI. October.

Towns, G.L. 1984. Technical Report: A Fisheries Survey of the Kalamazoo River. July and August 1982. Prepared by MDNR, Fisheries Division. Number 84-7. October 1. 24 pp.

U.S. EPA. 1990. Guidance on Remedial Actions for Superfund Sites with PCB Contamination. OSWER Directive No. 9355.4-01. Prepared by the U.S. Environmental Protection Agency, Office of Emergency and Remedial Response, Washington, DC. August. 68 pp.

U.S. EPA. 1995. Drinking Water Regulations and Health Advisories. Prepared by the U.S. Environmental Protection Agency, Office of Water, Washington, DC. May.

U.S. EPA. 1996. Calculation and Evaluation of Sediment Effect Concentrations for the Amphipod *Hyalella azteca* and the Midge *Chironomus riparius*. Assessment and Remediation of Contaminated Sediments (ARCS) Program. EPA 905-R96-008. U.S. Environmental Protection Agency. September. 28 pp.

U.S. EPA. 1997. Phase 2 Report — Review Copy. Further Site Characterization and Analysis. Volume 2C — Data Evaluation and Interpretation Report. Hudson River PCBs Reassessment RI/FS. U.S. Environmental Protection Agency, Washington, DC. February.

U.S. EPA. 1999. National Recommended Water Quality Criteria – Correction. EPA 822-2-99-001. U.S. Environmental Protection Agency, Office of Water. April.

U.S. FWS. 1992. Protocol for Handling and Processing Eggs for Contaminant Analysis. Prepared by East Lansing Field Office.

U.S. FWS and Stratus Consulting. 2000. Restoration and Compensation Determination Plan (RCDP): Lower Fox River/Green Bay Natural Resource Damage Assessment. Prepared by Stratus Consulting, Inc., Boulder, CO, for U.S. Fish and Wildlife Service, U.S. Department of the Interior, U.S. Department of Justice, Oneida Tribe of Indians of Wisconsin, Menominee Indian Tribe of Wisconsin, National Oceanic and Atmospheric Administration, Little Traverse Bay Bands of Odawa Indians, Michigan Attorney General. October 25.

Velleux, M. and D. Endicott. 1994. Development of a mass balance model for estimating PCB export from the Lower Fox River to Green Bay. *Journal of Great Lakes Research*. 20:416-434.

Williams, C.M. 1979. Comments Regarding Administrative Rules for PA-64 Hazardous Waste Management Act. December.

Wisconsin DNR. 1993. Development of Sediment Quality Objective Concentrations for PCBs in Deposit A, Little Lake Butte des Morts. Prepared by the Wisconsin DNR Sediment Management and Remedial Techniques Team. February.